# THE ENGINEER

## A Seven-Day Journal


### Launch of Steam Tanker "World Unity"

ON Tuesday there was launched successfully from the Barrow yard of Vickers-Armstrongs, Ltd., the oil tanker "World Unity," which is the first of two tankers of 31,000 tons deadweight which the company is building for the North American Shipping and Trading Company (London), Ltd. The naming ceremony was performed by Mrs. J. W. Platt, the wife of the managing director of the Anglo-Saxon Petroleum Company, Ltd. This latest addition to the world's tanker fleet is the largest built in this country. She has a length between perpendiculars of 625ft, by 86ft breadth moulded, by 45ft 9in depth to the upper deck, and is designed to carry a deadweight of 31,000 tons on summer draught at a sea speed of 15 knots. The ship has twin longitudinal bulkheads; longitudinal framing has been adopted on the shell throughout the length of the cargo oil tanks and forward hold and transverse framing at the ends. There are thirty cargo oil tanks and the structure is completely welded except for the upper deck stringer and the seams of the bilge strake. The ship is propelled by a single set of Parsons turbines of PAMETRADA design, driving a four-bladed 21ft 9in diameter propeller through double-reduction articulated gearing having built-up wheels and a fabricated gearcase. The machinery, which is capable of developing 12,500 s.h.p. continuously and a maximum of 13,750 s.h.p. with the propeller turning over at 100 r.p.m. and 103 r.p.m. respectively, takes steam at 420 lb per square inch and 740 deg. Fah. Steam is supplied by two Foster-Wheeler water-tube boilers having cast iron gilled economisers and burning oil fuel under forced and induced draught.

### Engineering Industries' Association Regional Display

AT the fourth display of the London region of the Engineering Industries' Association, which was held at the Royal Horticultural Society's New Hall, Westminster, on Tuesday and Wednesday last, some 130 member firms exhibited their products and gave details of their manufacturing facilities. This Association was founded in 1941 and provides an advice service to its members on the problems which arise from day to day in their business: questions on finance and taxation, costing in connection with Government contracts, export procedure and licensing, material and labour shortages, &c. The display held this week was the outcome of a move started in 1948, when members of several London groups took samples and photographs of their products or work to meetings of the Association. The successful results of those meetings in providing a basis for interchanging practical information, which supplemented the information given in *The National Capacity Gazette* of capacity and materials available, resulted in an extension of the scheme. In January, 1949, a one-day exhibition was held, and this was followed by a two-day exhibition in November of that year, which was repeated in 1950 and again this year. In these displays member firms and prospective customers are given the opportunity to inspect each other's products, discuss manufacturing capacities and generally get an up-to-date idea of the facilities available in the London region. At these displays each company makes a point of having on its stand senior executives and people who have the authority to discuss on the spot the problems of production and capacity required or available. A particular feature of this year's display was the showing of blueprints of work available for sub-contract by about twenty firms holding large orders under the defence programme. Member firms were able to inspect the drawings and, if they had capacity, were invited to tender for the work.

### The 36th International Motor Exhibition

THE annual motor exhibition organised by the Society of Motor Manufacturers and Traders was opened at Earls Court, London, on Wednesday last by the Minister of Supply, Mr. G. R. Strauss, and will close on Saturday, October 27th. The exhibition space this year occupies about 250,000 square feet and contains 520 stands. Of the sixty-four makes of cars displayed, half are British and seventeen are American and Canadian, with ten French, four Italian, and one German exhibit. The car section, however, is only one of seven, others being concerned with carriage work, accessories and components and tyres. In the caravan and light trailer section are caravans which range from the small 8ft class to a double-deck model, 22ft long, having double bedroom accommodation for four or five persons. In the marine section there are many classes of ocean and river-going motor boats and sailing craft, together with a display of suitable power units for them. Amongst these engines are petrol and diesel units with outputs ranging from 1½ h.p., and there is one particular model which, though started with petrol, cruises on paraffin. The Society held its annual dinner on Tuesday evening last, the principal speaker being the Viscount Jowitt, the Lord Chancellor. During the president's address, Mr. G. E. Beharrell, the president of the S.M.M.T., referred in his speech to the future of the motor-car in this country and the effect of economic changes during the last thirteen years. He stated that, whereas in 1938 it was considered possible to run a new car on a net income of £450 per annum, the minimum salary necessary to-day would be of the order of £1250. This fact, he thought, would drastically reduce the potential home market for cars when the present backlog of new orders had been eliminated.

### Report of the City Engineer of Manchester

THE annual report of the city surveyor and engineer of Manchester for the year ended March 31, 1951, probably gives a good idea of a typical year's work in any British city, under the present conditions of limited expenditure and with a great deal of work to be done. As might be expected, a large volume of maintenance work was carried out during the year, new works being somewhat restricted in their scope, although good progress was made with such works as housing, particularly at the Wythenshawe estate, where 2031 dwellings were completed and progress was made in developing the industrial areas of the estate, several leases having been negotiated and building work started on a 25-acre site. It is worthy of note that of the 75 miles of roads which carry the city's main traffic, 40 miles were surfaced with granite setts in 1943: 90 per cent of these granite sett roads have now been covered with asphalt. On the less important roads surfaced with granite setts a search has been made for a cheaper material than hot-rolled asphalt, which was used for the major roads, and experiments have been carried out with cold asphalt and hot bituminous macadam. Substantial progress has also been made in completing the Middleton connecting sewer, which is being constructed in tunnel, in very bad ground, compressed air being employed. The air pressure, from 3 lb to 32 lb. per square inch, is maintained by large stationary diesel-engined compressors, and the tunnel is lined with reinforced concrete segmental sections, the joints being caulked and the space between the lining and the ground filled with cement grout. Other sewerage works were in progress during the year. Mention cannot be made of the numerous other duties which were carried out during the year, but it may be said that substantial improvement in the plant at the engineer's disposal for cleansing and maintenance work was effected, and preparation of the development plan for the area, as required by the Town and Country Planning Act, was in progress.

### Structural Engineering

ON Thursday evening of last week, Mr. Walter C. Andrews, M.I.C.E., delivered his presidential address to the Institution of Structural Engineers, taking as his theme the development of structural engineering as applied to buildings during the past hundred years. In the course of his address Mr. Andrews said that in 1851 the principal materials in use for building were stone, brick and timber, and he pointed out that construction was relatively heavy in form. He went on to trace the subsequent development and use of other materials and to discuss changes in building design and practice, commenting that as structures became more and more complicated much ingenuity came to be shown in applying graphical methods of analysis. But, Mr. Andrews suggested, apart from the development of the frame, it could not be said that there had been any great changes in, or additions to, the various forms of structure since 1851. What had happened from time to time had been the application of new materials or new techniques to old forms. In some general conclusions Mr. Andrews expressed the view that structural engineers should beware of thinking they had the final answer to any problem, but should endeavour to keep an open mind. They ought also to appreciate, he thought, that they were not more ingenious than their predecessors of 1851, but that they had greater opportunities and better tools. What was most required, Mr. Andrews claimed, was the opportunity to apply new knowledge, use new materials, and develop new techniques without restraint or restrictions.

### Heavy Duty Engine Oils

THE Ministry of Supply has set up an advisory panel on heavy duty engine oils, which will include representatives of industry, as well as of the Ministry, War Office and Department of Scientific and Industrial Research. The panel, which is unpaid, is to be responsible for recommending approval of oils submitted under a new specification, governing the quality of such oils for the services. Engine tests will be carried out and the panel will make its assessments after studying reports of the tests and of inspections. The panel's terms of reference are to study reports of inspection of heavy duty engine oils submitted for qualification, and to study reports of engine tests and to examine relevant engine components; to assess, on the basis of such reports and examinations, the suitability of oils submitted for use by the services in ground equipment; and to recommend the acceptance of oils which, in the opinion of the panel, satisfy the performance requirements of the specifications. The chairman of the panel is Dr. F. T. Barwell, of the Department of Scientific and Industrial Research.

# The Form of an Aluminium Alloy Angle for Use as a Strut

By C. G. WATSON

HEREIN an account is given of the design of an aluminium alloy angle section giving greatest economy of material when used as a strut. The alloy used is that known as Noral 51ST. Its stress strain relationship is shown in Fig. 1. From that has been derived Fig. 2, in which stress is connected with tangential modulus of elasticity; and from

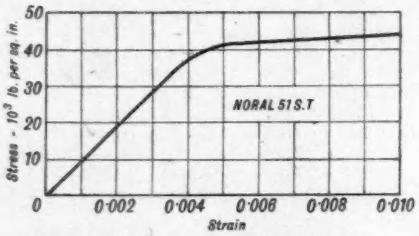



FIG. 1—COMPRESSIVE STRESS/STRAIN RELATIONSHIPS

that the Euler curve of Fig. 3 has been constructed.

The factors entering into the design of a section are:—

(*a*) Idiosyncrasy.
(*b*) Practical needs and limits.
(*c*) The outstanding leg.
(*d*) The Eulerian efficiency.
(*e*) The effect of torsion.

The inclusion of idiosyncrasy as a factor in design is a necessity, because, while an engineer's knowledge may be great, his ignorance may be greater. Consequently, calculation is a guide and not a determinant. What is determining is judgment, the integration, largely unconscious, of his experience and of his inheritance, of his feelings as well as of his reason; in fact, of his whole being. That means that behind judgment is idiosyncrasy. Besides, time does not permit of

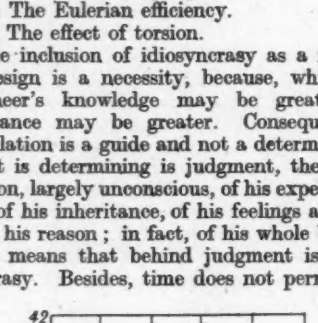



FIG. 2—RELATION BETWEEN STRESS AND MODULUS OF ELASTICITY

the exhaustive examination of all the known factors, or seeking the possibly unknown. That leads to selection. Behind selection is the idea. And that is why idiosyncrasy is of primary import. All that may be trite, but it merits the restatement. That idiosyncrasy is present herein will be apparent as the argument goes on.

Practical needs include robustness, i.e., ability to withstand damage during manufacture, transport and erection, room for bolts and parallelism at bolting faces. Among the limits is the relation of minimum thickness to maximum overall dimension, imposed by the extrusion process.

*The Outstanding Leg.*—Within the effective range of slenderness ratios the crippling stress of the outstanding leg may be taken as equal to

$$G \cdot B_{min.} \quad . \quad . \quad . \quad . \quad (1)$$

wherein $G$ is the modulus of elasticity in shear and

$$B = \frac{\Sigma t_1^3 b_1}{\Sigma b_2^3 t_2}$$

wherein $t_1$ and $b_1$ are the thickness and length of elements taken at right angles to the face

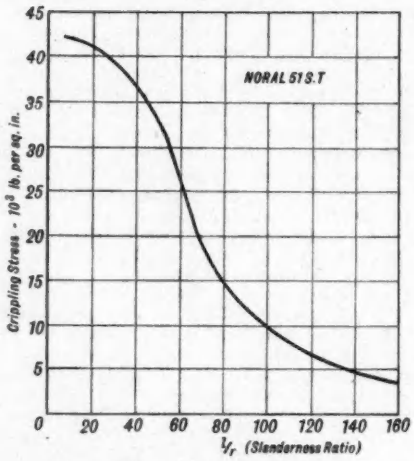



FIG. 3—EULER CURVE

of the flange, and $t_2$ and $b_2$ the thickness and length of elements taken lengthwise with the flange.

For practical cases, taking the thickness of the outstanding leg as unity, $B$ reduces to

$$\frac{b + \Sigma t_1^3 b_1}{b_2^3}$$

with negligible error. In that formula $t_1$ and $b_1$ are taken over only that part of the flange shaded in Fig. 4, $x$ being any point between $g$ and $f$.

Fig. 5 illustrates a typical example of the variation of $B$ with distance of $x$ from $g$, the point of junction of fillet with outstanding leg.

Fig. 6 shows the straight-line graph given by formula(1) when $G$ is taken as $10{\cdot}9 \times 10^6 / 2{\cdot}66$ (=4·1) and the position of the experimental results obtained by Baker and Roderick ("The Strength of Light Alloy

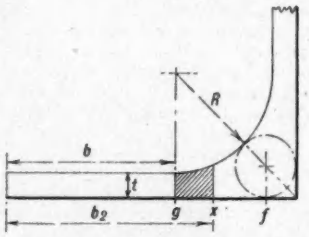
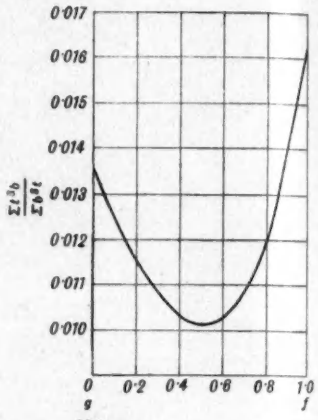



FIG. 4

Struts," Professor J. F. Baker and J. W. Roderick, Research Report No. 3, the Aluminium Development Association). Their section *A.S.* has been omitted because clearly in that case the length of outstanding leg is not decisive in determining crippling; *B.S.* has been included, although it is realised that its closeness to the graph may be fortuitous. The experimental results given for sections *C.S.* and *D.S.* do not permit of the exact determination of the effect of the outstanding leg, but the position of points *C* and *D* in the figure are considered reasonable. The points *E* and *F* may be taken as well established. Looking at the whole, the accuracy of formula (1) over the range covered may be taken as satisfactory until a better established method is available.

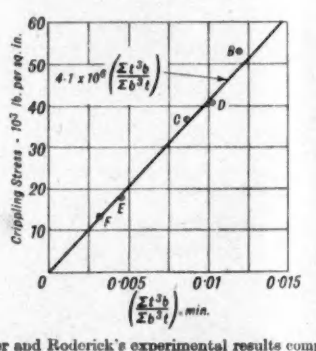
Fig. 7 shows the relation between $B_{min.}$ and length of outstanding leg and fillet radius.

From formula (1) and Figs. 2 and 7 the crippling stress of the outstanding leg of




Variation of $\frac{\Sigma t^3 b}{\Sigma b^3 t}$ from junction of fillet with outstanding leg and centre of inscribed circle.

FIG. 5




Baker and Roderick's experimental results compared with $\sigma = 4{\cdot}1 \times 10^6 \left(\frac{\Sigma t^3 b}{\Sigma b^3 t}\right)$ min.

FIG. 6

Noral 51ST angles has been derived. The results are plotted in Fig. 8.

*The Eulerian Efficiency.*—For any given form of section let

$r_a$ = least radius of gyration of unit area,
$r$ = least radius of gyration of any section of that form,
$A$ = cross-sectional area of that section.

Then

$$r_a = \frac{r}{\sqrt{A}} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Combining that with Euler's formula

$$\sigma = \frac{\pi^2 E}{\left(\frac{l}{r}\right)^2},$$

and the load formula

$$P = A\sigma,$$

we get

$$A = \frac{l}{\pi r_a}\sqrt{\frac{P}{E}} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

wherein

$E$ = modulus of elasticity,
$l$ = length of strut,
$P$ = load on strut, the other symbols being as before defined.

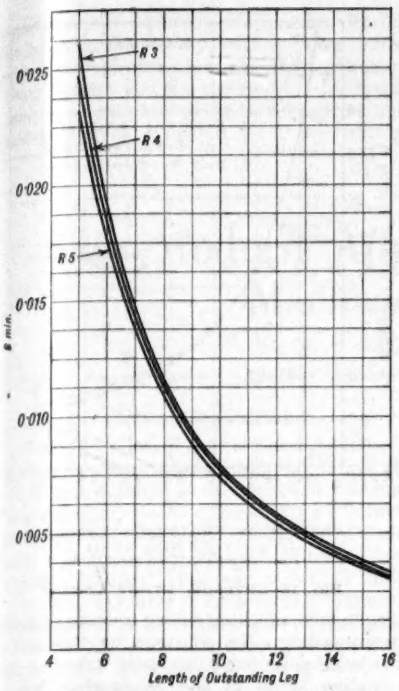



FIG. 7—CONNECTION BETWEEN LENGTH OF OUTSTANDING LEG, RADIUS OF FILLET, AND $B_{MIN}$

For any particular load and length of strut, and given modulus of elasticity, we get

$$A=\frac{K}{r_a},$$

wherein $K$ is a constant. That is to say, that the efficiency of a section as a strut is directly proportional to the radius of gyration of unit area of the form of section.

The formula, however, has limits imposed by the properties of the material and the section. For Noral 51ST sections with an outstanding leg the upward limit to the stress is given in Fig. 8 and the downward limit to the slenderness ratio is given in Fig. 3.

Substituting the value of $A$ given by the load formula in equation (2), transforming and multiplying by $l$, we get

$$\frac{l}{\sqrt{P}}=\frac{\left(\frac{l}{r}\right)r_a}{\sqrt{\sigma}} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

wherein $\sigma$=crippling stress. That supplies a means whereby the efficiencies of sections of different form may be compared throughout the range of use.

*Eccentricity.*—The preceding formula applies to centrally loaded struts. In practice, truly

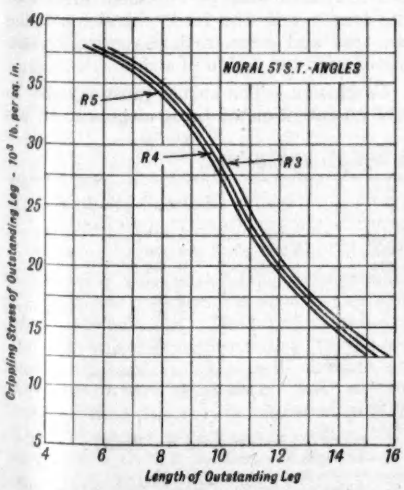



FIG. 8

central loading is unattainable. The causes of that may be divided into (*a*) defects in material, (*b*) initial curvature, (*c*) applied eccentricities. For the moment let us consider the first two. In this matter we may take advantage of steel experience, which enables us, following Timoshenko ("Theory of Elastic Stability," 1936), to put the eccentricity covering defective material and

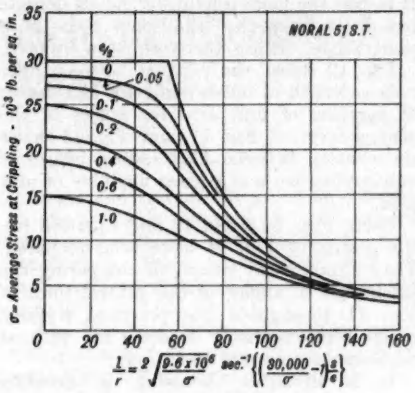



FIG. 9—SECANT STRUT CHART

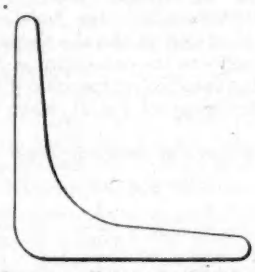


FIG. 10—GENERAL FORM OF ANGLE SECTION FOR TORSIONAL EFFICIENCY

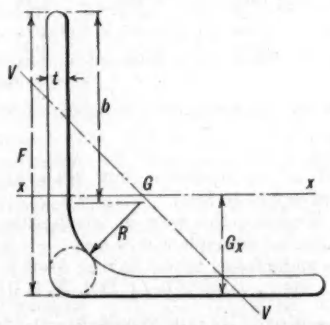



FIG. 11—GENERAL FORM OF PRACTICAL ANGLE SECTION

initial curvature at 0·0025 times the length of the member concerned.

Eccentricity of loading involves bending. Bending involves bringing the section modulus into account. The section modulus varies with the form of section; moreover, for its relation to the radius of gyration varies. The Perry formula assumes a constant relation between radius of gyration and section modulus. It is therefore unsuitable for comparing the performance of different forms of section, unless the eccentricity factor is based on a known relationship between $r$ and $Z$, and varied as the relationship varies. Even so, a different curve would be needed for each form of section. The secant formula avoids that difficulty. It may be found in Timoshenko, (*loc cit*) equation (50), page 38.

That formula, put into the form in which it has been used for calculation, is

$$\frac{l}{r}=2\sqrt{\frac{E}{\sigma}}\sec^{-1}\left\{\left(\frac{\sigma_{max}}{\sigma}-1\right)\frac{s}{e}\right\}$$

wherein $s$=core radius and $e$=eccentricity. It is, however, unsuitable for direct calculation of efficiency. Accordingly a number of charts have been prepared with different maximum stresses suitable for use with different lengths of outstanding leg. An example of such a chart is given in Fig. 9

*Section Modulus.*—For any given form of section let

$Z_a$=section modulus of unit area,
$Z$=section modulus of any section of that form,

Then

$$Z_1=\frac{Z}{\sqrt{A^3}} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

*The Effect of Torsion.*—It is assumed that, within the general form, the proportions giving greatest Eulerian efficiency will also

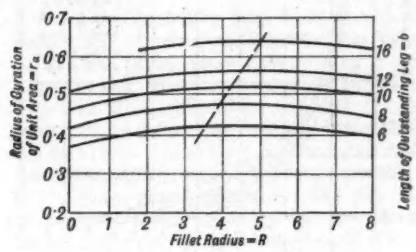



FIG. 12

give greatest torsional efficiency. Support for that assumption is given by the experimental evidence available. That evidence, however, is meagre. Let us look at it. Take Fig. 49, page 91, of Baker and Roderick, where a strut curve, i.e., a curve connecting crippling stress with slenderness ratio, is given for each of six angles. The great differences of proportion of the sections tested make comparison difficult, but if angles of comparable outstanding leg be taken, two pairs of such angles, i.e., *BS*, *DS* and *ES*, *FS*, show that the larger the fillet radius the nearer does the strut curve approach the Euler curve. Section *AS* has length of leg so much shorter than the others that it is of little value in this comparison. There remains section *CS*. That, seemingly, does not support the assumption, but as we do not know to what extent radius of fillet and length of outstanding leg affect the strut curve, great weight should not be attached to it. (It may be that a torsion formula, taking into account the phenomena illustrated by Fig. 5, would rectify the apparent discordance.) From Inglis ("Analytical Determination of Shear Stresses and Torsion Stresses in Beams and Shafts of Any Given Uniform Section," Professor Sir Charles Inglis, Paper No. 5633, the Institution of Civil Engineers) we learn that the torsion stress decreases as the fillet radius increases

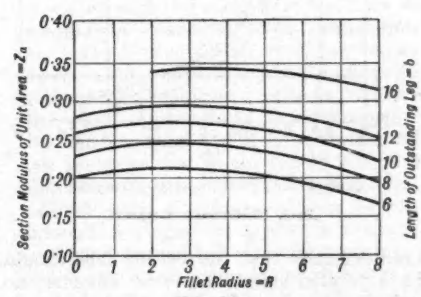



FIG. 13

and may assume that that indicates an increase of efficiency, possibly with an optimum value. As will appear later, we shall see that the Eulerian efficiency increases as the fillet radius increases to an optimum value for each length of outstanding

leg, the optimum ranging about 4 (all radii and lengths herein are in terms of thickness of flange). From the curves it would appear that increase of fillet radius above 4 would not appreciably increase the efficiency, for the strut curve of the section with that fillet radius approximates to the Euler curve over much of its length. That it does not do so over the whole of the working range may be explained by the length of the outstanding leg. That it crosses the Euler curve may be explained by the arbitrary modulus of

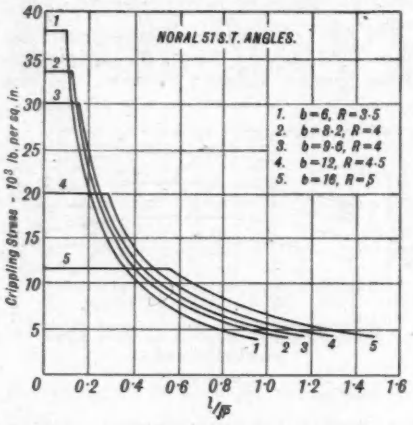
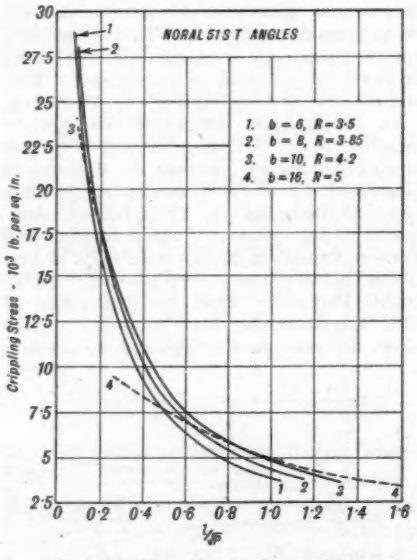



FIG. 14—STRUT CHART WITH CENTRAL LOADING

elasticity used in determining that curve. (Proof strength is an abomination; its origin is commercial, its use is unscientific, its results are misleading; it should be abolished.) From all of those considerations it would appear that the assumption, if not strictly true, conforms to fact without appreciable error.

*The Angle.*—A deduction from Inglis's Fig. 21 is that the general form of an angle for greatest torsional efficiency should be substantially as shown here in Fig. 10. Practical




Central loading with normal eccentricity

FIG. 15—STRUT CHART

need demands that the bolting face should have parallel sides. There is, however, no sufficient reason why the rounded corners should not be retained. On the contrary, seeing that the rounded corners add to the robustness and facilitate handling, there is good reason why they should be retained. Accordingly, the general form of an angle to secure high efficiency should be that shown in Fig. 11.

The rounding of the flange tips by a semicircle is simple and obvious. The rounding of the apex could be effected in either of two ways: (1) by a radius equal to that of the circle touching the flange faces at the points where $B$ is a minimum; (2) by a radius equal to that of the circle touching the curve of the fillet and the face of each flange. The second way is slightly the more efficient. It is, too, the more convincing, i.e., it departs but little from the traditional form of a sharp angle. It has, therefore, been adopted.

Fig. 12 shows the relation between fillet radius, length of outstanding leg and radius of gyration of unit area for angles of the general form of Fig. 11, and Fig. 13 shows the relation between fillet radius, length of outstanding leg and section modulus of unit area.

Using Figs. 3, 8 and 12 and equation (4), the graphs of Fig. 14 have been prepared. They afford ready means of comparing the efficiencies of angles of the general form of Fig. 11 throughout the practical working range when centrally loaded, but without allowance for normal eccentricity.

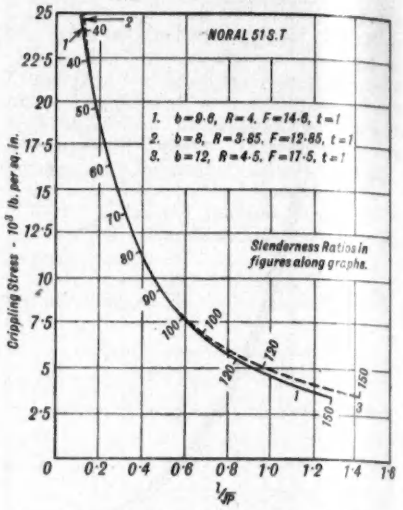
It is advisable, however, in deciding upon a standard design, to take into account the effect of normal eccentricity, i.e., $0{\cdot}0025\,l$. Accordingly, use has been made of Figs. 8, 12 and 13 and the secant formula graphs similar to the one shown in Fig. 9, to construct graphs for comparison of angles to the general design of Fig. 11, when centrally loaded as to intention but with normal eccentricity as to fact.

To illustrate the way in which that has been done an example will be best:—

The angle taken is one having $b=9{\cdot}6$ and $R=4$. Its $r_a$ value is 0·51 and $Z_a$ is 0·265, whence $s\left(=\frac{Z_a.r.}{r_a}\right)$ is $0{\cdot}265r/0{\cdot}51=0{\cdot}52r$.

$l/r=100/2=50$; $e/s=0{\cdot}0025\times100/2\times0{\cdot}52=0{\cdot}24$. From the chart, Fig. 9, when $l/r=50$ and $e/s=0{\cdot}24$, the crippling stress is 19,500 lb. From equation (2), $A=(r/r_a)^2=(2/0{\cdot}51)^2=15{\cdot}4$. Therefore crippling load $P=19{,}500\times15{\cdot}4=300{,}000$ lb, and therefore $l/\sqrt{P}=100/\sqrt{300{,}000}=0{\cdot}183$. Other values of $l/\sqrt{P}$ are worked out in similar fashion.

The results are plotted in Fig. 15. Other results have not been shown in order to avoid overcrowding. In constructing the curves the maximum stress has been taken as the crippling stress of the outstanding leg as previously determined. From all the curves which have been drawn Fig. 16 has been prepared. That gives, within 1 per cent, the best performance at present attainable with Noral 51ST angles. From the figure it will be apparent that, for practical purposes, the standard angle should have an outstanding leg of 9·6 and a fillet radius of 4. For convenience, slenderness ratios have been marked alongside the curves. The table gives the principal properties of the standard section.


NORAL 51S.T
1. b=9·6, R=4, F=14·6, t=1
2. b=8, R=3·85, F=12·85, t=1
3. b=12, R=4·5, F=17·5, t=1
Slenderness Ratios in figures along graphs.
Crippling Stress - 10³ lb. per sq. in.
l/ρ

Central loading with normal eccentricity
$l$=length of strut in inches
$P$=crippling load on strut in lbs.

FIG. 16—OPTIMUM STRUT CHART

Fig. 16 serves as a strut chart, whereby the stress and consequently the cross-sectional area may be obtained direct from the length and the load, thereby avoiding the trial and error method commonly associated with the design of struts.

*Conclusion.*—The author must say that he has no intention of being dogmatic in any

TABLE I.—*Properties of Noral 51ST Angles to Fig. 11 with Length of Outstanding Leg=9·6t, Radius of Fillet=4t, and Radius of Apex=1·272t*

| $A$ | $F$ | $t$ | $r$ | $Z$ | $r_x$ | $Z_x$ | $G_x$ |
|---|---|---|---|---|---|---|---|
| 1 | 2·62 | 0·180 | 0·510 | 0·266 | 0·778 | 0·313 | 0·683 |
| 2 | 3·70 | 0·254 | 0·720 | 0·752 | 1·10 | 0·884 | 0·965 |
| 3 | 4·54 | 0·311 | 0·882 | 1·38 | 1·35 | 1·62 | 1·18 |
| 4 | 5·24 | 0·359 | 1·02 | 2·13 | 1·56 | 2·50 | 1·37 |
| 5 | 5·86 | 0·401 | 1·14 | 2·98 | 1·74 | 3·49 | 1·53 |
| 6 | 6·42 | 0·440 | 1·25 | 3·91 | 1·91 | 4·59 | 1·67 |
| 7 | 6·93 | 0·475 | 1·35 | 4·93 | 2·06 | 5·79 | 1·81 |
| 8 | 7·41 | 0·508 | 1·44 | 6·02 | 2·20 | 7·07 | 1·93 |
| 9 | 7·86 | 0·538 | 1·53 | 7·18 | 2·33 | 8·44 | 2·05 |
| 10 | 8·28 | 0·568 | 1·61 | 8·41 | 2·46 | 9·88 | 2·16 |

Other sizes may be calculated by multiplying values for $A=1$ by $\sqrt{A}$ for $F$, $t$, $r$, $r_x$, and $G_x$; and by $\sqrt{A^3}$ for $Z$ and $Z_x$.

TABLE II.—*As for Table I, but with Argument of Flange Width*

| $F$ | $t$ | $A$ | $r$ | $Z$ | $r_x$ | $Z_x$ | $G_x$ |
|---|---|---|---|---|---|---|---|
| 1 | 0·0685 | 0·146 | 0·195 | 0·0148 | 0·297 | 0·0174 | 0·261 |
| 2 | 0·137 | 0·584 | 0·389 | 0·118 | 0·594 | 0·139 | 0·521 |
| 3 | 0·206 | 1·31 | 0·583 | 0·399 | 0·891 | 0·470 | 0·782 |
| 4 | 0·274 | 2·34 | 0·778 | 0·946 | 1·19 | 1·11 | 1·04 |
| 5 | 0·343 | 3·65 | 0·973 | 1·85 | 1·49 | 2·17 | 1·30 |
| 6 | 0·411 | 5·25 | 1·17 | 3·19 | 1·78 | 3·76 | 1·56 |
| 7 | 0·480 | 7·15 | 1·36 | 5·07 | 2·08 | 5·97 | 1·83 |
| 8 | 0·548 | 9·34 | 1·56 | 7·57 | 2·38 | 8·91 | 2·09 |

Other values may be determined by multiplying those for $F=1$ by $F$ for $t$, $r$, $r_x$ and $G_x$; by $F^2$ for $A$; and by $F^3$ for $Z$ and $Z_x$.

In both tables:

$A$=Cross-sectional area,
$F$=flange width,
$t$=thickness of outstanding leg,
$r$=least radius of gyration,
$r_x$=radius of gyration about $X$—$X$ axis,
$Z$=least section modulus,
$Z_x$=section modulus about $X$—$X$ axis,
$G_x$=distance of centre of gravity from outside face of flange.

unsubstantiated statement appearing herein; he has omitted "in my opinion" and similar qualifying phrases because they interrupt the argument and tire the reader. Nevertheless, he has no hesitation in using the angle section arrived at herein. For the assumptions made are reasonable and by no means wilder than many commonly accepted in practice, and there is no sufficient reason to suppose that the factor of safety (truly a factor of ignorance) would be any less efficacious in the one case than in the other.

# The Modern Approach to Electrical Machine Analysis

By W. J. GIBBS, D.Sc., M.I.E.E.

No. II—(*Continued from page 469, October 12th*)

## Two-Axis Theory

*Transformation of Currents and Voltages.*—Owing to the rotation of the rotor, the angle $\theta$ is a function of time, and therefore it is a variable to be differentiated whenever it follows $p$ in a term. Since the $p$'s also refer to the currents, the equations are non-linear differential equations, and their direct solution is a matter of considerable difficulty. Therefore it is most desirable to find some substitutions that will render the equations linear. The substitutions used need not, of course, have any physical significance.

The substitutions that make the equations linear are these :—

$$\begin{aligned} i_a &= i_d \cos\theta + i_q \sin\theta \\ i_b &= i_q \cos\theta - i_d \sin\theta \end{aligned} \quad . \; . \; . \quad (14)$$

where the new variables $i_d$ and $i_q$ are introduced without any particular interpretation being attached to them. Substitutions of this kind are also called transformations.

The transformation of currents involves a corresponding transformation of voltages. It is important to realise that once a given transformation of currents has been decided on, the corresponding transformation of voltages is not at our disposal. The substitution of currents given by equations (14) represents a change in the system of description of a machine under some definite conditions of load and supply. It is obviously essential that quantities like power input and output, load angle, and other performance quantities shall be found to be the same whatever system of description is used. In other words, the invariants of the system must be preserved, and the transformation of the voltages is subject to this condition.

The transformation equations for the voltages can be found by using the condition that the power input must be invariant. First solve equations (14) for $i_d$ and $i_q$. The result is

$$\begin{aligned} i_d &= i_a \cos\theta - i_b \sin\theta \\ i_q &= i_b \cos\theta + i_a \sin\theta \end{aligned} \quad . \; . \; . \quad (15)$$

Now the condition that $e_d$ and $e_q$ must satisfy is :—

$$\begin{aligned} i_a e_a + i_b e_b &= i_d e_d + i_q e_q \\ &= i_a e_d \cos\theta - i_b e_d \sin\theta + i_a e_q \sin\theta + \\ &\quad i_b e_q \cos\theta \\ &= i_a (e_d \cos\theta + e_q \sin\theta) + i_b (e_q \cos\theta \\ &\quad - e_d \sin\theta). \end{aligned}$$

This condition is satisfied when

$$\begin{aligned} e_a &= e_d \cos\theta + e_q \sin\theta \\ e_b &= e_q \cos\theta - e_d \sin\theta \end{aligned} \quad . \; . \quad (16)$$

Thus, with this particular transformation, the voltages transform in exactly the same way as the currents. The terms $e_d$ and $e_q$ are the new voltages corresponding to the new currents $i_d$ and $i_q$. The new voltages and currents do not depend on any physical interpretation that may be conferred on them. They are simply mathematical entities introduced as a device in the solving of non-linear differential equations. Nevertheless, in order to distinguish them from the phase voltages and currents they can be described as the two-axis voltages and the two-axis currents, without any definition being attached to these terms other than the mathematical definition of equations (14) and (16).

*The Two-Axis Equations.*—Before substituting the new variables into equation (8), write down the identical equations :—

$$L_S + L_D \cos 2\theta = L_d \cos^2\theta + L_q \sin^2\theta$$

and

$$-L_D \sin 2\theta = (L_q - L_d) \sin\theta \cos\theta.$$

The substitution then reduces to

$$\begin{aligned} e_d \cos\theta + e_q \sin\theta &= p(L_d i_d + L_{ad} i_f) \cos\theta + \\ &\quad p L_q i_q \sin\theta + r_a (i_d \cos\theta + i_q \sin\theta), \end{aligned}$$

where, as before, $p$ refers to both $i$ and $\theta$.

Perform the differentiation indicated by $p$ by parts and use the symbol $\dot{\theta}$ to represent $d\theta/dt$; so that $p$ will now refer only to $i$.

$$\begin{aligned} e_d \cos\theta + e_q \sin\theta &= \cos\theta (L_d p i_d + L_{ad} p i_f) \\ &\quad - \dot{\theta} \sin\theta (L_d i_d + L_{ad} i_f) + \\ &\quad \sin\theta \, (L_q p i_q) + \dot{\theta} \cos\theta L_q i_q + \\ &\quad r_a (i_d \cos\theta + i_q \sin\theta). \end{aligned}$$

The equation is true for all values of $\theta$ and the result of putting $\theta$ equal to zero is

$$e_d = L_d p i_d + L_{ad} p i_f + \dot{\theta}(L_q i_q) + r_a i_d \quad . \; . \quad (17)$$

On the other hand, the result of putting $\theta = 90$ deg. is

$$e_q = L_q p i_q + r_a i_q - \dot{\theta}(L_d i_d + L_{ad} i_f) \quad . \; . \quad (18)$$

Equation (18) can also be obtained by the substitution of the new variables into equation (9).

The substitutions into equation (12) are much simpler, and the following equation results :—

$$e_f = L_f p i_f + L_{ad} p i_d + r_f i_f \quad . \; . \quad (19)$$

Equations (17), (18) and (19) are the required two-axis equations of voltage, and they are linear differential equations. It is advantageous for what follows to put them into the form of equation (13), separating out the coefficients from the variables and putting them into separate boxes, thus :

$$\begin{bmatrix} e_f \\ e_d \\ e_q \end{bmatrix} = \begin{bmatrix} r_f + L_f p & L_{ad} p & \\ L_{ad} p & r_a + L_d p & L_q \dot{\theta} \\ -L_{ad}\dot{\theta} & -L_d \dot{\theta} & r_a + L_q p \end{bmatrix} \cdot \begin{bmatrix} i_f \\ i_d \\ i_q \end{bmatrix} \quad \ldots (20)$$

An empty compartment in a box, such as that in the top row third column of the centre box, is understood by convention to represent zero. If the rule described on page 469 is applied to the matrix equation (20), the three equations (17) to (19) are determined.

The function $\dot{\theta}$ is the instantaneous speed of the rotor, but although in most problems it is a variable quantity, (even in synchronous machines), yet, wherever possible, it is assumed to be unaffected by conditions of loading or of disturbance, so that in the solution of the equations $\dot{\theta}$ is treated as if it were constant. It must be borne in mind that this assumption is not quite true, because every disturbance involves a transient change in the speed of the rotor. When the disturbance is small there is a simple method of taking the effects of speed change into account that will be described later. If the machine is operating at synchronous speed, $\theta$ can be replaced by $\omega$, where $\omega$ is the frequency of the supply in electrical radians per second.

With $\dot{\theta}$ treated as constant, the currents give the only derivatives in the equations, which are now therefore linear. When the boundary conditions are known, they can readily be solved, either by replacing $p$ by $d/dt$ and using classical methods of solution, or by retaining $p$ and using operational methods.

When the equations have been solved the results are in terms of the two-axis quantities. The phase quantities are then substituted for the two-axis variables by equations (14) and (16). Equations (1) and (2) are then used to get the three-phase values from the two-phase. However, it is convenient to change straight from the two-axis quantities to the three-phase quantities, and this can be done by first combining the two transformations given by equations (1) and (14).

The result of the combination is :

$$\begin{aligned} i_1 &= i_d \cos\theta + i_q \sin\theta \\ i_2 &= i_d \cos(\theta - 120 \text{ deg.}) + i_q \sin(\theta - 120 \text{ deg.}) \\ i_3 &= i_d \cos(\theta + 120 \text{ deg.}) + i_q \sin(\theta + 120 \text{ deg.}) \end{aligned} \quad . \; . \; . \; . \; . \quad (21)$$

By similarly combining equations (2) and (16) it is found that

$$\begin{aligned} e_1 &= e_d \cos\theta + e_q \sin\theta \\ e_2 &= e_d \cos(\theta - 120 \text{ deg.}) + e_q \sin(\theta - 120 \text{ deg.}) \\ e_3 &= e_d \cos(\theta + 120 \text{ deg.}) + e_q \sin(\theta + 120 \text{ deg.}) \end{aligned} \quad . \; . \; . \; . \; . \quad (22)$$

Thus the complete performance of the machine under any condition of loading or disturbance is found without any incursion into what physical meaning can be attached to the two-axis currents and voltages.

*Rotational and Transformer Voltages.*—Reverting to equation (20), when the machine is at rest, $\dot{\theta}$ is zero and with it the corresponding voltages. For this reason these voltages are called the rotational voltages because they only arise through the motion of the rotor conductors in the field. On the other hand, it will be shown later that when the machine is running, with steady state operation at synchronous speed, only the resistance drops and the rotational voltages appear; that is, all terms with $p$ are zero. Therefore, the particular voltages in equation (20) with $p$ in the term are called transformer voltages, because they only arise through changes in the field and are independent of rotation.

Thus the effect of introducing the two-axis variables is to divide the set of voltages associated with the variable inductances into components, rotational and transformer; this is the distinctive feature of the two-axis theory. The separation is to some degree artificial; the rotational voltages are those that would appear if the conductors moved in a constant field, and the transformer voltages are those that would appear if the conductors were stationary in a changing field.

*Steady State Conditions.*—When balanced sinusoidal voltages are applied to the armature windings, with the machine on steady load at synchronous speed, the equations can be made very much simpler, because they can be changed from differential to ordinary algebraic equations. Since under steady state conditions the field current is purely direct current, $pi_f$ is zero.

The frequency of the phase currents, $i_a$ and $i_b$, is the frequency of the supply, namely, $\omega$ radians per second. Let the

maximum value of $i_a$ throughout the cycle be $I_m$. Then

$$i_a = I_m \sin(\omega t - \phi) \quad . \quad . \quad . \quad (23)$$

where $\phi$ is a constant angle introduced because the zero value of $e_a$ is taken to be coincident with zero time, and $i_a$ may lag behind $e_a$ in time by the angle $\phi$.

The variable $i_b$ has the same maximum value as $i_a$, but it is 90 deg. ahead of $i_a$ in time. Therefore

$$\begin{aligned} i_b &= I_m \sin(\omega t - \phi + 90 \text{ deg.}) \\ &= I_m \cos(\omega t - \phi) \quad . \quad . \quad . \quad (24) \end{aligned}$$

Substitution of these values of $i_a$ and $i_b$ in equations (15) gives

$$\begin{aligned} i_d &= I_m [\sin(\omega t - \phi)\cos\theta - \cos(\omega t - \phi)\sin\theta] \\ &= I_m \sin(\omega t - \phi - \theta) \quad . \quad . \quad . \quad . \quad . \quad (25) \end{aligned}$$

Since at synchronous speed $\dot{\theta} = \omega$, by integration

$$\theta = \omega t + \delta,$$

where $\delta$ is another constant angle different from $\phi$, called the load angle. Substituting this value of $\theta$ in equation (25) gives

$$i_d = -I_m \sin(\delta + \phi) \quad . \quad . \quad . \quad (26)$$

By proceeding in exactly the same way with $i_q$, it is found that

$$i_q = I_m \cos(\delta + \phi) \quad . \quad . \quad . \quad (27)$$

Now, since $I_m$, $\delta$ and $\phi$ are all constants,

$$pi_d = pi_q = 0 \quad . \quad . \quad . \quad . \quad . \quad (28)$$

Therefore for steady state conditions, in equation (20) substitute $\omega$ for $\dot{\theta}$ and put $p = 0$. For $\omega L$ write the reactances corresponding to the inductances. The result is the equation

$$\begin{vmatrix} e_f \\ e_d \\ e_q \end{vmatrix} = \begin{vmatrix} r_f & & \\ & r_a & x_q \\ -x_{ad} & -x_d & r_a \end{vmatrix} \cdot \begin{vmatrix} i_f \\ i_d \\ i_q \end{vmatrix} \quad \ldots (29)$$

This equation gives the steady state performance of the machine even when there are damper circuits present. It has just been shown that the transformer voltages in the circuits would be zero; there would be no rotational voltages because the damper circuits are on the stator, and there would be no applied voltages because damper circuits are short-circuited. Therefore, under steady state operation, there are no currents flowing in the damper circuits, and the performance is given by equation (29).

Because the centre array in equation (29) contains impedances, an appropriate name for it is the impedance array or, better still, the impedance matrix. If the impedance matrix of any machine of whatever type is known, it is possible to write out at once the steady state equations of performance of that machine, simply by putting the column matrix of voltages in front of it and the column matrix of currents behind it, and forming the matrix equation. Interpretation of this equation by the rules given yields the separate equations of performance.

The name impedance matrix is extended to the centre array of equation (20), where the compartments contain operational impedances. If the operational impedance matrix of any machine of whatever type is known, then the differential equations of voltage of the machine can be written out. It is evident that the operational impedance matrix is, from an analytical point of view, the most important entity the machine possesses.

## Damper Circuits

In practice nearly all synchronous machines have damper circuits. They may be simply the eddy current paths of solid-pole shoes, or field collars, or there may be a pole-face winding either of the phase-wound or the squirrel-cage type.

A field collar acts definitely in the direct axis. Eddy current paths are symmetrical about the two axes of geometrical symmetry, and so can be represented by two windings, one in the direct axis and the other in the quadrature axis. Pole-face windings of the phase-wound type are usually symmetrical about the axes, but those of the squirrel-cage type are often displaced. Nevertheless, as an approximation it is permissible to regard the pole-face windings as far as effects are concerned as consisting of a direct axis and a quadrature axis winding.

Fig. 4 shows the arrangement with the

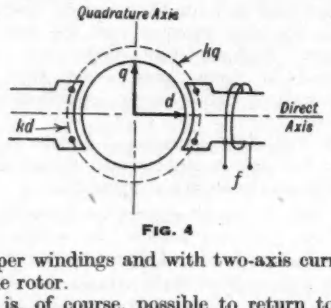



FIG. 4

damper windings and with two-axis currents in the rotor.

It is, of course, possible to return to the method of No. I (pages 467-69) and develop first the equations in terms of the actual phase currents and voltages and then make the appropriate transformation to direct and quadrature axis quantities. It is preferable, however, to use the two axis theory to derive the required five equations quickly.

One of the great advantages of using matrix methods is the possibility of developing routine methods that can be applied as a regular procedure to all types of electrical machines. The methods are simple and only require the most elementary knowledge of matrix conventions, little more than has already been explained.

The aim of the particular routine to be described now is to be able to write down at sight the operational impedance matrix of any type of machine. The differential equations of voltage then follow automatically from the conventional reading of the matrix equation already described. When it is impossible to write out the impedance matrix at sight it can be quickly derived by a routine manipulation from an impedance matrix that can be written out at sight.

The method is best explained by considering how equation (20) could be written out at sight. The machine has three windings, a field winding in the direct axis on the stator and two rotor windings, one acting on the direct axis and the other on the quadrature axis. Note that the method depends on the use of two-axis quantities; it is desirable to repeat that it cannot be used in such machines as inductor generators that have dissymmetry on both sides of the air-gap, for they cannot be described by two-axis quantities.

Since there are three windings, set out a box with three rows and columns, and select an order of windings, say, $f$, $d$ and $q$. At this stage it is useful to label the rows and columns in the order selected. It is also

| | $f$ | $d$ | $q$ |
|---|---|---|---|
| $f$ | $r_f$ | | |
| $d$ | | $r_a$ | |
| $q$ | | | $r_a$ |

helpful to associate the labels on the left with the voltages, and the labels at the top with the currents. Now the main diagonal of the box is the diagonal of compartments running from top left to bottom right; these compartments have the same label to their rows and columns.

The resistances are first written into the main diagonal. The reason for this is that the resistance drop in, say, the field winding is associated with the row labelled $f$, and it can only be due to current in the same winding, the current associated with the column labelled $f$; no current in any other winding can possibly cause a resistance drop in the field winding. Therefore, since $r_f$ is associated only with row $f$ and column $f$, it must go into the compartment common to that row and column. Similarly, the other resistances must go into the main diagonal in their appropriate compartments.

Exactly the same arguments apply to the self-inductances, and they, too, must be put into the main diagonal added to their corresponding resistances, and multiplied by $p$, because the induced voltage is not $Li$, but $Lpi$. All the mutual inductances can now

| | | |
|---|---|---|
| $r_f + L_f p$ | | |
| | $r_a + L_d p$ | |
| | | $r_a + L_q p$ |

be put into the off-diagonal compartments. The current in the $d$ winding causes a voltage to be induced in the $f$ winding by virtue of the mutual inductance between them. Thus, $L_{fd}$ is put into row $f$ and column $d$, and so on until all compartments are filled, thus:

| | | |
|---|---|---|
| $r_f + L_f p$ | $L_{fd} p$ | $L_{fq} p$ |
| $L_{fd} p$ | $r_a + L_d p$ | $L_{dq} p$ |
| $L_{fq} p$ | $L_{dq} p$ | $r_a + L_q p$ |

Each mutual inductance is multiplied by $p$. The mutual inductance between $d$ and $f$ is the same as that between $f$ and $d$, and therefore the mutual inductances are balanced about the main diagonal.

Some of these mutual inductances are obviously zero. All the windings are in axes of magnetic symmetry, and thus there can be no mutual inductance between any direct axis and any quadrature axis winding. Therefore $L_{fq}$ and $L_{dq}$ are zero and can be omitted. $L_{fd}$ is usually written $L_{ad}$. Thus the matrix becomes

| | | |
|---|---|---|
| $r_f + L_f p$ | $L_{ad} p$ | |
| $L_{ad} p$ | $r_a + L_d p$ | |
| | | $r_a + L_q p$ |

The only quantities not yet put in are the rotational voltage terms. These terms should only appear in the rotor rows $d$ and $q$. Inspection of the impedance matrix of equation (20) shows that the rotational voltage terms do appear only in rows $d$ and $q$, and that every coefficient of $p$ in row $d$ appears again in row $q$ in the same column, but with $p$ replaced by $-\dot{\theta}$. Similarly, every coefficient of $p$ in row $q$ appears again in row $d$ in the same column, but with $p$ replaced by $+\dot{\theta}$. This is because a current that gives an induced voltage in one axis of a rotor winding must also give a rotational voltage in the other axis of the winding. This procedure can therefore be adopted as a rule for setting down the rotational voltage terms in the matrix. In connection with this rule, one should remember that in row $d$ the sign is unchanged, while in row $q$ the sign is reversed.

Applying this rule to the machine under

consideration gives the following matrix :—

| | | |
|---|---|---|
| $r_f+L_Fp$ | $L_{ad}p$ | |
| $L_{ad}p$ | $r_a+L_dp$ | $L_q\dot{\theta}$ |
| $-L_{ad}\dot{\theta}$ | $-L_d\dot{\theta}$ | $r_a+L_qp$ |

and this matrix is identically the impedance matrix of equation (20), written down by a routine method that can be applied to any machine, provided the windings are not interconnected in any way, and the machine can be described in terms of two-axis quantities.

*Synchronous Machine with Damper Windings.*—The salient-pole synchronous machine with damper windings fulfils these conditions, and therefore the impedance matrix of the machine can be written out at sight from the diagram of Fig. 4. There are five independent windings, and therefore five rows and columns in the matrix. The mutual inductance between the $q$ winding and the $kq$ winding is denoted $L_{aq}$. There are now three mutual inductance values in the direct axis because there are three windings in that axis. But it is found in practice that they can be assumed equal in magnitude without appreciable loss of accuracy, and therefore all three are written $L_{ad}$.

The resistances $r_{kd}$ and $r_{kq}$ differ considerably from each other and retain their separate symbols. The self-inductances $L_{KD}$ and $L_{KQ}$ have capital letters for their suffixes to show that they represent the total inductances and not the leakage inductances.

Using these symbols, the impedance matrix of the machine can be written down thus :—

| | $f$ | $kd$ | $kq$ | $d$ | $q$ |
|---|---|---|---|---|---|
| $f$ | $r_f+L_Fp$ | $L_{ad}p$ | | $L_{ad}p$ | |
| $kd$ | $L_{ad}p$ | $r_{kd}+L_{KD}p$ | | $L_{ad}p$ | |
| $kq$ | | | $r_{kq}+L_{KQ}p$ | | $L_{aq}p$ |
| $d$ | $L_{ad}p$ | $L_{ad}p$ | $L_{aq}\dot{\theta}$ | $r_a+L_dp$ | $L_q\dot{\theta}$ |
| $q$ | $-L_{ad}\dot{\theta}$ | $-L_{ad}\dot{\theta}$ | $L_{aq}p$ | $-L_d\dot{\theta}$ | $r_a+L_qp$ |

.....(30)

The labels are not really necessary; they are put in as a guide in filling up the matrix, particularly the mutual inductance terms. They can be omitted in practice because the suffixes of the quantities in the main diagonal show the order of windings that has been selected. The five differential equations of the machine now follow automatically.

Some of the advantages of this matrix method are now apparent. Putting the coefficients of the currents into a box reveals at once such simplifications as the use of one value of mutual inductance for all three windings in the direct axis. Another advantage is that the empty spaces in the matrix are prominent, and therefore it is almost impossible to omit terms inadvertently or to get coefficients misplaced. Other advantages will appear later in this analysis.

It was explained earlier that under steady state conditions the damper circuits carry no currents, and can be left out of the equations. Thus, equation (29) represents the steady state performance of the salient-pole synchronous machine with damper circuits.

## Transient and Subtransient Quantities

*Transient Conditions.*—Transient and subtransient effects are caused by some disturbance, cyclic or otherwise. The analysis then develops new and fictitious inductances and reactances, whose definitions are based on a particular type of disturbance, namely, the sudden short circuit of all phases of the machine at a moment when it is operating under steady state conditions. It is assumed that, following the short circuit, the machine is allowed to settle down to a new steady state condition of short circuit.

When the equations given by the impedance matrix (30) have been solved for the sudden short-circuit condition, the phase currents and voltages can be substituted for the two-axis quantities by means of equations (21) and (22). The final solution consists of these terms :—

(*a*) A steady state component alternating at supply frequency.

(*b*) A component called the transient component with a time constant of a few seconds, alternating at supply frequency.

(*c*) A component called the subtransient component with a time constant of a fraction of a second, alternating at supply frequency.

(*d*) A component called the asymmetrical component with a time constant of a fraction of a second; this component does not alternate.

(*e*) A component called the second harmonic component with the same time constant as (*d*); this component alternates at twice the supply frequency.

(*f*) A component that is so small and so brief as to be physically indeterminate.

The components are not of equal importance, and in many applications of the solution interest is centred in the first three terms.

It is the general practice to assume that, following a short circuit, there are three independent periods: first, a subtransient period lasting a few cycles only, then a transient period lasting a few seconds, and a final indefinite period of steady-state running. The characteristics during the final steady state running can be obtained from the steady state equation (29).

*Transient Period.*—It is assumed that when the transient period starts the subtransient effects have completely died away, and that the damper circuits are therefore carrying no currents and can be ignored. The impedance matrix is therefore that of equation (20).

The changes produced by the three-phase short circuit are the same as would be produced by suddenly applying to the armature terminals, with the circuit dead, a set of voltages equal and opposite to those actually appearing at the terminals before the short circuit. The field winding has therefore to be regarded as short circuited throughout.

Thus during the transient period the machine is supposed to behave as though it possessed an operational impedance matrix of the form

| | |
|---|---|
| $r_a+L_d'p$ | $L_q'\dot{\theta}$ |
| $-L_d'\dot{\theta}$ | $r_a+L_q'p$ |

.....(31)

where $L_d'$ and $L_q'$ are fictitious inductances called transient inductances.

But what are the equations in fact? The appropriate starting point is the set of equations (17) to (19), and since $e_f$ is to be considered zero, $i_f$ can be eliminated by normal algebraic processes. The resulting two equations are :

$$e_d=\left(r_a+L_dp-\frac{L_{ad}^2p^2}{r_f+L_Fp}\right)i_d+L_q\dot{\theta}i_q$$

$$e_q=(r_a+L_qp)i_q-\left(L_d-\frac{L_{ad}^2p}{r_f+L_Fp}\right)\dot{\theta}i_d.$$

From these two equations can be extracted the actual operational impedance matrix for the transient condition, and it is :

| | |
|---|---|
| $r_a+\left(L_d-\dfrac{L_{ad}^2p}{r_f+L_Fp}\right)p$ | $L_q\dot{\theta}$ |
| $-\left(L_d-\dfrac{L_{ad}^2p}{r_f+L_Fp}\right)\dot{\theta}$ | $r_a+L_qp$ |

.....(32)

This impedance matrix gives rigorously the equations of performance of the machine after short circuit and after the effects called subtransient have died away with the asymmetrical component, and the damper circuits can be considered inoperative.

*Definition of Transient Inductances.*—In the matrix (32) the expression inside the brackets is not a simple inductance and cannot be treated as such; simplification is necessary, and it takes the form of neglecting the field winding resistance. It is then possible to write

$$L_d'=L_d-\frac{L_{ad}^2}{L_F} \quad . \quad . \quad . \quad (33)$$

and

$$L_q'=L_q \quad . \quad . \quad . \quad . \quad . \quad (34)$$

where $L_d'$ and $L_q'$ are pure inductances, although fictitious. Substitution of (33) and (34) into the matrix (32) gives the matrix (31), which is the form of impedance matrix sought. Neglecting the field winding resistance is called the "constant flux linkage theorem" in the usual expositions.

Equation (34) shows that the transient inductance in the quadrature axis is the same as the total inductance $L_q$. As a result there is said to be no quadrature axis transient inductance.

If both sides of equation (33) are multiplied by the synchronous speed $\omega$, all the inductances change to reactances, giving

$$x_d'=x_d-\frac{x_{ad}^2}{x_F} \quad . \quad . \quad . \quad . \quad (35)$$

where $x_d'$ is called the transient reactance. In the per unit system, unit speed is synchronous speed; therefore in that system inductances are equal numerically to their corresponding reactances. It has therefore become a common practice to refer to reactances when inductances are really meant.

Changing a matrix containing $N$ rows and columns to one containing $(N-1)$ rows and columns is called the reduction of the matrix. For instance, the impedance matrix of equation (20) has just been reduced to a matrix (32) having one less row and column. This reduction can be done quickly by a routine method now to be described.

*Routine Reduction of Matrices.*—If the voltage applied to any winding is zero, the row and column corresponding to that winding in the impedance matrix can be eliminated without writing out the equations and solving them. Suppose there is the set of equations

| | | | | | |
|---|---|---|---|---|---|
| | $a$ | $b$ | $c$ | $i_1$ | |
| $e_2$ | $=$ $d$ | $e$ | $f$ | $\cdot$ $i_2$ | |
| $e_3$ | $g$ | $h$ | $k$ | $i_3$ | |

.....(36)

then

$$ai_1+bi_2+ci_3=0.$$

Hence

$$i_1=-\frac{bi_2+ci_3}{a}.$$

Similarly,

$$e_2=di_1+ei_2+fi_3$$

$$=i_2\left(e-\frac{bd}{a}\right)+i_3\left(f-\frac{cd}{a}\right) \quad . \quad . \quad (37)$$

and

$$e_3 = i_2\left(h - \frac{bg}{a}\right) + i_3\left(k - \frac{cg}{a}\right) \quad . \quad . \quad (38)$$

Equations (37) and (38) in matrix form become :

$$\begin{bmatrix} e_2 \\ e_3 \end{bmatrix} = \begin{bmatrix} e - \frac{bd}{a} & f - \frac{cd}{a} \\ h - \frac{bg}{a} & k - \frac{cg}{a} \end{bmatrix} \cdot \begin{bmatrix} i_2 \\ i_3 \end{bmatrix}$$

This result indicates a simple rule for eliminating a row and column of an impedance matrix when the winding concerned can be considered short circuited. In the matrix (36) the top row and the left-hand column are to be eliminated. Consider the centre compartment containing the element $e$. After the elimination it becomes

$$e - \frac{bd}{a}$$

where $b$ is the element common to the row to be eliminated and the column containing $e$, $d$ is the element common to the column to be eliminated and the row containing $e$, while $a$ is the element common to both row and column to be eliminated.

The change in the elements $f$, $h$ and $k$ follow the same rule. The application of this rule to the impedance matrix (20) leads directly to the reduced matrix (32).

*(To be continued)*

# "D.58" Class Locomotives for New South Wales Railways

No. I—By G. H. PAULIN

THE island continent of Australia is a country of vast distances. Probably few people realise clearly how vast are these distances. It is possible to travel by rail from Perth, in the extreme west of Australia, to Brisbane, which city is not far from the most easterly point of the continent. The rail distance is 3308 miles.

The total route mileage of Australian Government Railways open for traffic (June 30, 1944) is 27,215. This mileage is mostly single track and the figure gives some idea of the great distances between the capital cities and between these cities and the more remote areas served by the railways. For instance, from Perth to Adelaide, the next easterly capital, is 1622 miles. Melbourne to Sydney 590 miles. Brisbane to Cairns 1043 miles. Sydney to Broken Hill 698 miles. Perth to Wiluna 705 miles.

Over very great areas the land is dry, largely waterless and relatively flat. Other parts are rugged and mountainous and the building of the railways here has presented problems very different from those arising in the construction and maintenance of track in the dry areas. For instance, on the Sydney-Brisbane line, through Wallangarra, the altitude reached is 4473ft (at Ben Lomond Station). This altitude is approaching fairly nearly to the maximum (5337ft) on the main line of the Canadian Pacific Railway where it crosses the continental divide near Stephen, B.C.

The topography of New South Wales has meant problems of considerable degree for the locomotive engineers. The State has a route mileage of 6127·43, all 4ft 8½in gauge track. There are long and heavy hauls from the wheat country to sea ports and from the coal-mining centres to Sydney and the industrial areas. The coal haulage from Lithgow over the Blue Mountains is a particularly arduous duty, involving the surmounting of a 3503ft altitude, with a subsequent almost continuous fall to 67ft (Sydney) in 88 miles.

Concomitant with the development of the whole country, the remarkable growth of the capital cities (Sydney is the second white city of the Empire, with nearly 1¼ million population) and the rapid extension of industrialisation, there has been the inevitable increase in railway traffic. The goods and mineral tonnages soon grew beyond the capacity of the earlier available motive power.

In order to enable heavier trains to be hauled at higher speeds, the Chief Mechanical Engineer's Department designed a new class of locomotive—the "D.57." This engine is a 4–8–2, with three cylinders, the valves of the outside cylinders operated by conventional Walschaerts gear, the inside valve obtaining its motion through conjugated gear derived from the two outside valves, as in the Gresley gear.

There are twenty-five of these locomotives in operation. The first was built in August, 1929 and with the loads for which they were designed and for speeds up to 40 m.p.h., these engines have given good service. The conjugated valve gear, up to the speed for which it was intended, has functioned satisfactorily.

The principal duties of the "D.57" class are haulage of wheat and wool between Junee and Sydney on the main Southern line, a distance of 299½ miles, the line reaching at Cullerin a maximum altitude of 2395ft above sea level; and the handling of heavy coal trains between Lithgow and Sydney.

The maximum grade on the Lithgow line is 1 in 33, and the minimum curve is 8 chains radius. Over the section Blackheath-Enfield, loads of 1500 tons behind the tender are handled at 20 m.p.h. on grades of 1 in 66. This is possible on the "up" journey as wagons, both four-wheeled and bogie types, are fitted with grade control valves in the air brake system. The valves delay the release from the triple valves and this provides sufficient time for the Westinghouse brake pump to maintain normal pressure throughout the system—main reservoir, train pipe and auxiliary reservoir.

The "D.58" class, which is described in this article, is employed on similar work over the same parts of the system.

In the dry seasons and over considerable portions of the railway system, dust is a factor, among other factors, of much importance in the maintenance of rolling stock. The Chief Mechanical Engineer had the question of maintenance of efficiency of locomotives continually under close study

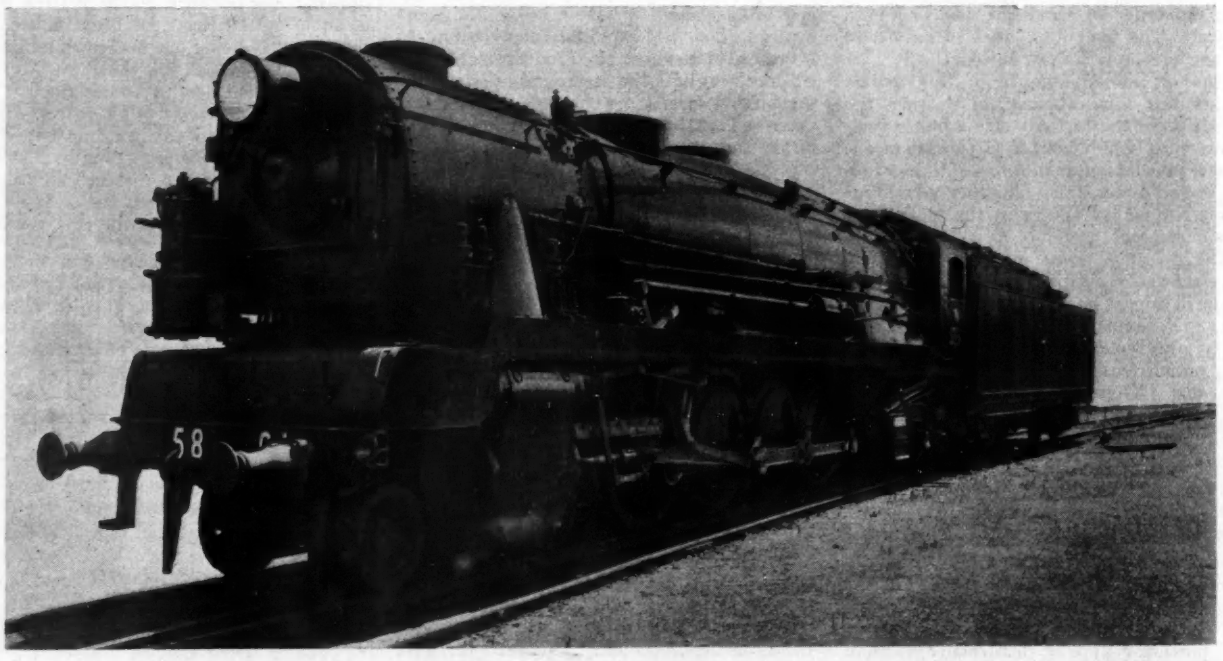
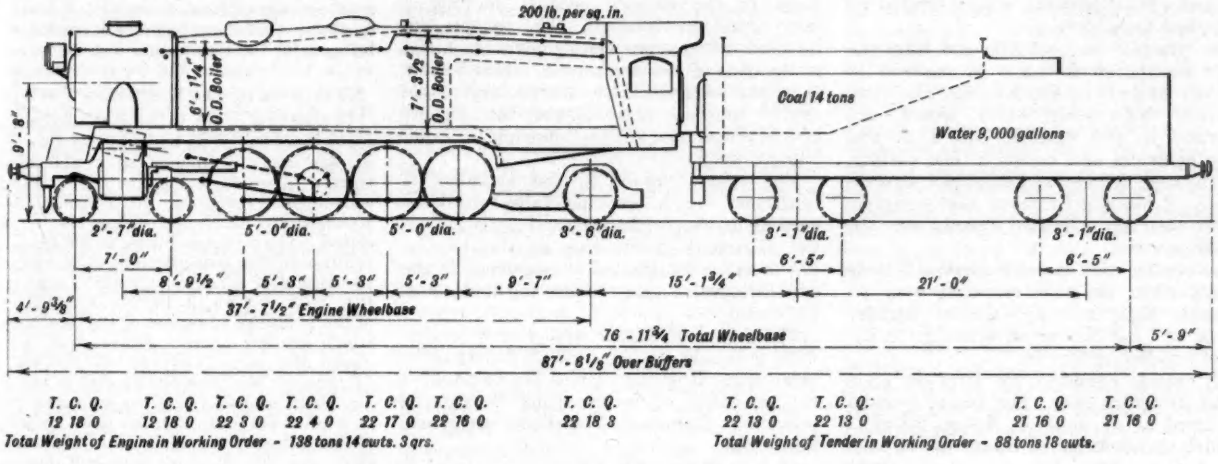



FIG. 1—CLASS "D.58" LOCOMOTIVE No. 5801

and in 1950 a new class of heavy freight locomotive was put into service. This locomotive is the "D.58" class and the main features follow the "D.57." As a result, however, of the studies of the conditions in which the "D.57" engines operated, the designers were able to introduce, in the "D.58," new and interesting changes. Chiefly they are:—

(1) Complete redesign of valve gear.
(2) Complete redesign of cross-head, small end, big-end, connecting-rod and coupling rods.
(3) Spherical small end bearing.




GENERAL ARRANGEMENT OF CLASS "D.58" LOCOMOTIVE

(4) Modified boiler design.
(5) Improved design of cylinders.
(6) 12in trick ported piston valve.
(7) Multiple valve regulator.
(8) New design of engine bogie with S.K.F. roller bearing axleboxes.
(9) New design of dynamically balanced coupled wheels.

Our illustrations show a general view of engine 5801 (the first of the "D.58" class to go into traffic) and the general lay-out of the engine and tender, together with the weight distribution and principal dimensions.

Table I shows principal particulars of engine and boiler.

TABLE I

| | |
|---|---|
| Cylinders (three), dia. and stroke | 21½in by 28in stroke |
| Piston valves dia. | 12in |
| Wheels: | |
| Coupled, dia. | 5ft |
| Bogie, dia. | 2ft 7in |
| Rear truck, dia. | 3ft 6in |
| Boiler pressure | 200lb per square inch |
| Heating Surfaces (evaporative): | |
| Firebox and C.C. | 259 square feet |
| Tubes and flues | 3094 square feet |
| Arch tubes | 37 square feet |
| Total evaporative | 3390 square feet |
| Superheater | 773 square feet |
| Grate area | 65 square feet |

Weights:

| | In steam tons cwt qr | Empty tons cwt qr |
|---|---|---|
| On coupled wheels | 90 0 0 | 78 11 0 |
| On bogie | 25 16 0 | 21 6 0 |
| On rear truck | 22 18 3 | 18 16 0 |
| Engine total | 138 14 3 | 118 13 0 |
| Tender | 88 18 0 | 42 1 0 |
| Total (engine and tender) | 227 12 3 | 160 14 0 |
| Maximum axle load | 22 18 3 | 20 5 0 |

| | |
|---|---|
| Tractive effort (at 85 per cent B.P.) | 56,000 lb |
| Adhesion factor | 3·6 |
| Wheel base: | |
| Engine | 37ft 7½in |
| Total engine and tender | 76ft 11¾in |
| Length (over buffers, engine and tender) | 87ft 6⅛in |

## BOILER

The boiler is constructed in carbon steels, with no alloys in firebox or shell. The barrel has a maximum diameter outside of 7ft. 3¼in, tapering down to 6ft 1½in at the smokebox tube plate; 20ft ⅜in between tube plates. 165 tubes of 2¼in outside diameter are provided. Forty flue tubes, 5½in outside diameter, accommodate the superheater elements. The small tubes have a pitch of $3\frac{1}{16}$in, with minimum bridge of ⅜in. The firebox is extended at the front end to form a conventional combustion chamber.

Five 3in outside diameter arch tubes are provided.

The firebox is 7ft 3½in wide inside with a length of 9ft $1\frac{1}{16}$in.

Ashton safety valves (three) each 3½in diameter are provided. The valve nearest the cab is set to lift at the working pressure, the centre valve at 2 lb per square inch above working pressure and the third valve, on the dome, is set to lift at 5 lb per square inch above the working pressure.

A power stoker is employed (type M.B.), Nathan live steam injectors are used. The forty element superheater is type M.L.S., by The Superheater Company, Ltd., London.

Examination of the evaporative heating surfaces and grate area, in relation to cylinder volume, indicates that the designers have adopted a somewhat higher cylinder volume relative to nominal boiler capacity than is the case with recent locomotives built in Britain and America.

Table II shows comparisons of the latest British Railways "Pacific" type engine, Class "7MT"; two Pennsylvania Railroad freight engines, classes "Q1" and "Q2," and the "D.58" class.

It will be seen that the grate area of the "D.58" class, in relation to the total evaporative heating surface, is in excess of any of the other locomotives shown. The ratio fire-box heating surface/grate area also shows a similar condition.

The grate area of 65 square feet is really a nominal figure as the mechanical stoker distributor inside the firebox takes up approximately 4 square feet. The net area is then approximately 61 square feet. The free area through tubes and flues in relation to net grate area, is 12·3 per cent, a figure similar to the values applying in the "A1" class E. and N.E., and "Merchant Navy" class Southern Region locomotives of British Railways.

The "D.58" boiler has a steam space of 130 cubic feet and water space of 512 cubic feet.

Comprehensive road steaming tests have not yet been carried out, as the demands on motive power and the difficulties experienced in getting sufficient quantities of coal of a consistent grade have precluded anything in the nature of precise technical investigation of detail. Figures obtained up to date have shown a maximum rate of evaporation of 46,142 lb per hour. Temperatures of smokebox gases are around 550 deg., with occasional rise to 600 deg. Fah. Smokebox vacuum, in front of diaphragm, 5in w.g. Superheated steam temperature up to 630 deg. Fah. Equivalent evaporation per lb of coal (12,000 B.T.U.) varied with the firing, between 8 lb and 13 lb, with an average of 9·57 for all tests made.

It would seem that the items indicated in the lower two lines of the table should mean a free steaming boiler. It is a fact that the "D.58" class locomotives are regarded well in this respect by drivers and operating staff.

These boilers are now standard for the "D.57" and "D.58" classes. Some of

TABLE II

| | British Railways, Class "7 MT" | Pennsylvania Rail Road, Class "Q 1" | Pennsylvania Rail Road, Class "Q 2" | "D.58" class |
|---|---|---|---|---|
| Piston area, square feet (PA) | 4·36 | 9·92 | 10·41 | 7·56 |
| Total evaporative heating surface, square feet (HS) | 2474 | 5518 | 6725 | 3390 |
| Heating surface, firebox, square feet (FB) | 210 | 580 | 725 | 259 |
| Grate area, square feet (GA) | 42 | 98 | 121·7 | 65 |
| Firebox and CC volume, cubic feet | 273 | — | — | 385 |
| HS/PA | 568 | 556 | 647 | 449 |
| GA/PA | 9·63 | 9·88 | 11·69 | 8·59 |
| HS/GA | 59 | 56·5 | 55·4 | 52·1 |
| FB/GA | 5·00 | 5·92 | 5·96 | 3·99 |

the "D.57" engines have been fitted with the "D.58" type boilers and have been for some time in regular service with them.

It is felt that the comparison of a mixed traffic engine with engines designed specifically for freight working is justified. The British Railways Class "7MT" on many duties will inevitably be required to face conditions where sustained heavy working is essential.

### Engine and Main Framing

The main framing consists of a unit steel casting, the cross-ties being cast integral. The coupled wheel axlebox horn guides are provided with adjustable wedges located on the trailing horn faces.

The cylinders are cast iron and form the saddle for the smokebox; attachment to the main frame is by fitted bolts. The three cylinders, with their valve chests, are comprised in two castings, the L.H. and centre cylinders and chests in one casting, with the R.H. cylinder and chest in a separate casting. A machined vertical joint (coupling the two castings) is located directly over the R.H. frame bar.

This construction is convenient and lends to production of good castings, with an incidental high insurance against foundry defects, or total loss of all cylinders in the case of accident in service.

The outside cylinders are arranged on a horizontal centre line. The inside cylinder is inclined at an angle of 9 deg. 24 min., in order to allow for clearance of the connecting-rod over the leading axle. To keep this inclination at a minimum the leading axle is cranked a limited amount.

The order of crank phasing, rotating forward, is right, left, centre, the respective crank angles being right-left 120 deg.; left-centre 128 deg. 30 min.; centre-right 111 deg. 30 min. During the design study of the valve gear functioning it was found desirable to introduce this asymmetry of crank phasing. It provided the compensation necessary to ensure the best possible steam distribution. There is no audible unevenness in the exhaust beats.

The centre crank is balanced, the attachment of the balance weights showing a very sound construction. The weights are dovetailed into appropriate grooves machined in the ends of the crank webs. This feature is in line with the most modern large diesel engine practice and ensures the highest possible insurance against loosening or other balance-weight trouble.

The steam supply to the cylinders is controlled by a multiple-valve regulator located in the smokebox, and arranged on the saturated steam side of the header. Fig. 3 shows the general arrangement of the cylinders, valve gear, connecting and coupling-rods.

The coupled wheels are a new design with provision for adjustment for dynamic balancing. Rotating masses are balanced—no balancing of reciprocating weights is provided. The coupled axleboxes are grease lubricated.

*(To be continued)*

# Hospitals, Institutions and the Engineer

## INSTITUTION OF ENGINEERS-IN-CHARGE*

IN a little book called "The L.C.C. Hospitals—A Retrospect," published by the London County Council in 1949, it is stated that surely the most far-reaching, and perhaps the most romantic of all accretions to the Council's functions, was the transfer to the Council on April 1, 1930, under the Local Government Act, 1929, of the whole of the rate-maintained hospitals of London, except, of course, those mental hospitals which already belonged to the Council. The transferred hospitals had up till then been administered by the Metropolitan Asylums Board (a central poor law authority covering the whole county) and by twenty-five separate boards of poor law guardians. Before these transfers the Council had administered sixteen mental institutions; the additions brought the total of the L.C.C. hospitals to ninety-eight, with 71,711 beds—by far the largest number of hospitals under a single local government authority in the world.

The book from which I have extracted these particulars deals only with hospitals; but that great aggregation was, for the engineer, far from constituting the whole increase. For, under the same Act, there were simultaneously transferred to the Council from the boards of guardians many large institutions, casual wards, residential schools, and children's homes.

### The Duties of the Chief Engineer

As part of its organisation for dealing with its important new tasks the Council assigned to its Chief Engineer responsibility for the maintenance of all buildings and structures, as well as for all engineering work ordinarily so called. The latter included some civil engineering and much mechanical and electrical engineering, in the design and execution of all new engineering works and of extensions and improvements to the existing plants, and in the operation and maintenance of the whole. New buildings and extensions and improvements of existing buildings were in the main designed and carried out by the Council's Architect with the collaboration of the Chief Engineer, who was responsible for the installations. In the mental hospitals, however, the Chief Engineer, who had control of the directly employed labour in the building trades, was responsible for the design and execution of all building works which would bring the workmen into contact with patients. And in all the establishments there were very many minor building works of alteration, addition and improvement which could most conveniently be done by the maintenance forces or included in maintenance contracts, and which therefore were assigned to the Chief Engineer.

[A number of slides were then shown to illustrate the equipment that came within the province of the Chief Engineer's Department. From relatively unimportant items of equipment, such as sinks, sanitary fittings, radiators, &c., and kitchen and bathroom fittings, the show of slides went on to illustrate X-ray plant, equipment of operating theatres and large sterilisers for dressings, &c., and later larger engineering plants, such as complete laundries fitted with washing machines, hydro-extractors and ironing machines, calorifying plant, boiler plant—the typical example showed three Lancashire boilers, 30ft long by 8ft diameter—generating plant, automatic telephone exchanges, &c. Finally it was stressed that building maintenance work was done by the department.]

That completes my illustrations, but there are many aspects of the work not included. There were large dining halls, recreation halls with stage appliances and cinema apparatus, churches and chapels with organ blowers and sometimes special lighting, workshops for the occupation or training of patients and inmates, equipped with plant for a variety of industries from carpentry and upholstery to soda water manufacture.

Some establishments had their private water supplies from deep wells, with pumping, water softening and chlorinating plants. There were some sewage pumps and sewage disposal plants. There were tennis courts, gymnasia and swimming baths. Among the civil engineering works carried out were sea walls and groynes for coast protection, a tunnel under the Southern Railway to give direct access between Dulwich Hospital and St. Francis Hospital, road construction and maintenance, and the construction of reinforced concrete water towers. And on the Horton Estate near Epsom, on which are five large mental hospitals with a population of over 10,000 patients and staff, the department operated and maintained a railway with about 5½ miles of track and some bridges, for the receipt and distribution of coal to the boiler-houses and for domestic use.

### Magnitude of the Engineers' Operations

In speaking of the value of the buildings and plant there has to be borne in mind the change in the value of money since the nineteen-thirties to which my figures refer. It will be convenient, therefore, to consider another standard by which the values can be appreciated. The late Asa Binns, in his Presidential Address to this Institution in 1936, stated that the capital of the Port of London Authority at that time was about £40,000,000. The value of the buildings and plant of the establishments which are our present subject was estimated about the same time at £37,000,000, only 7½ per cent less than the capital of the P.L.A. Mr. Binns also said that the enormous amount of mechanical and electrical plant required for the operation of the docks and for dealing with ships and cargoes of all sizes and descriptions represented a capital cost of over £6,000,000: £5,500,000 was the estimated value of the mechanical and electrical plant in the L.C.C. hospitals and institutions. Mr. Binns said that the average number of men employed on the engineering work of the Port Authority, either by direct labour or through contractors, exceeded 3000. The Chief Engineer's directly employed staff in the hospitals and institutions numbered over 2500 and I do not think there can often have been less than another 500 employed by contractors. It seems fair, then, to say that the engineers' work in these hospitals and institutions was of the same order of magnitude as in the Port of London Authority.

For the financial year 1938–39 the Council's estimates provided for the maintenance by the Chief Engineer's Department of the buildings, plant and engineering services an amount of over £760,000. This figure does not include fuel, gas, electricity, and water. In addition, there was provision, partly in maintenance estimates and partly in capital estimates, of nearly £1,500,000 for new works, extensions, alterations and improvements to be carried out during the year, and of this, about £450,000 was for work to be done by the Chief Engineer's Department; the balance was for building works to be carried out by the Council's Architect and for the provision of furniture and medical equipment. The estimates for work to be done by the Chief Engineer's Department in that one year, therefore, amounted to over £1,200,000.

Many of the new works were wholly or predominantly of an engineering character, as in complete new boiler or laundry installations, the centralisation of heating and hot water services, the complete re-wiring of a hospital's electrical installations, or the substitution of electric lifts for obsolete hydraulic lifts. Others would consist of the installations in new ward blocks, operating theatre units, out-patient departments, nurses' homes, or other new accommodation, the buildings for which were undertaken by the Council's Architect. The dimensions of new works were of all grades, from the large projects just mentioned down to the provision of a weighbridge or a few sterilisers, refrigerators, surgeons' basins or nightlights.

### Organisation

The Chief Engineer's Department of the London County Council is organised in divisions,

*Presidential Address by Robert Chalmers, October 10th. Extracts.

each headed by a Divisional Engineer directly responsible to the Chief Engineer. Naturally, then, the principal means adopted for handling the work I have tried to describe was the creation of a new division called the Public Institutions Division. All of the engineering and building trades staffs previously employed by the Metropolitan Asylums Board and by the Boards of Guardians at each establishment became members of that Division. So did those of the Council's own mental hospitals previously employed in the separate small department of the Mental Hospitals Engineer. He now became the first Public Institutions Divisional Engineer in the Chief Engineer's Department, bringing with him his head office staff, who were joined by the staff transferred from the department of the Engineer-in-Chief of the Metropolitan Asylums Board. That combination was further recruited as occasion demanded.

The mental hospitals were very large establishments, each with accommodation for 2000 to 3000 patients besides resident staff. Their buildings were therefore extensive and, as we have seen, much new building work, besides maintenance, was carried out by the direct employment of labour. At each of them there was an engineering trades staff under an engineer-in-charge and a building trades staff under a general foreman of building. At the other hospitals and institutions, although the engineering was in many cases equally onerous, the buildings were much less extensive and one general foreman of building sufficed for a group of them. At each of them, therefore, both the engineering and the building trades staffs were under the executive control of the engineer-in-charge on the spot, who was directed to comply with the advice of the building trades foreman in all matters of building trades technique. On building trades work carried out by contract the general foreman acted as clerk of works, the engineer-in-charge deputising for him while he visited other establishments. On engineering trades contract works the engineer-in-charge was the clerk of works, occasionally supplemented if such works were unusually extensive.

The principal link between the engineers-in-charge and head office consisted of a section of area engineers, the head of which had also under him a sub-section whose duties were the study of operating efficiencies, and particularly boiler-house efficiencies, in which the division maintained a very high standard.

At head office there were also sub-divisions for mechanical engineering, electrical engineering and building, each with their sections, the members of which prepared plans, specifications and estimates for works of the respective kinds. They also inspected works in progress, applied, on occasion, their special knowledge to special maintenance problems and, in the case of the building surveyors, directed generally the building trades foremen.

The heads of the area engineers and of the sub-divisions reported to the divisional engineer or his deputy, and to them there was also attached the head of the administrative and clerical staff allocated to the division, whose head office staff numbered, by 1938, 150 in all.

The division was, of course, linked in many ways with other parts of the Chief Engineer's Department. Relation was particularly close with the Electrical Division for consistency of practice between the hospitals and institutions and the many other L.C.C. buildings and activities. Advice or assistance was available, when required, from the divisions concerned with branches of civil engineering. Observance of the Council's Staff Regulations and of trade union agreements was guided by the Establishment Branch, and accounts dealt with by the Accounts Branch of the administrative and clerical staff under the department's chief clerk and establishment officer.

### Progress and Frustration

Except during the years of "economic blizzard," the Council's capital estimates for the hospitals and mental hospitals alone were at the rate of £900,000 to £1,000,000 a year. Those figures represent, on the one hand, the Council's wishes and, on the other, their staff's forecasts, at first perhaps rather optimistic, of what it would be practicable to accomplish. But whereas in 1935–36 the expenditure was only £527,000 against estimates of £907,000, there was continuously better performance until in 1938–39 the expenditure reached £952,000 against estimates of £1,000,000. That progress represents the building up and integration of organisation in the departments of the Chief Engineer and the Architect. It shows, too, how nearly the ambition to make these services throughout the finest, as well as the largest, in the world might have come to be realised, but for the catastrophe of 1939 and after.

### End of the L.C.C. Hospital Service

After the war, just as the obstacles to the progress of engineering and building works were beginning to show signs of diminishing, the introduction in Parliament of the National Health Service Bill dashed any hope of restoring, under the Council, a team that could rival the pre-war accomplishments. The resulting Act was passed in November, 1946, and it was subsequently decided that it should come into force on July 7, 1948, when practically all the country's hospitals would be transferred to the Minister of Health.

During the interval of twenty months new authorities were constituted which were to assist the Minister in the administration of the nationalised hospital services. They included fourteen Regional Hospital Boards, which would have the general control of all hospitals other than teaching hospitals, for which there were to be separate Boards of Governors. London's hospitals were divided among four regions, each extending far beyond the County of London, the boards of which were known respectively as the North-West, North-East, South-East and South-West Metropolitan Regional Hospital Boards. All Regional Boards were advised to consider the appointment of Regional Medical Officers, Secretaries and Architects.

To us here, and to all who understand how utterly hospitals are dependent upon sound engineering services, with all which that implies, it must remain a cause of profound astonishment that after all those twenty months of preparation the first advices of the Ministry to these new authorities about engineering is dated July, 1948, the month in which they actually assumed their functions. Consequently, the London County Council was asked to continue for a period the services of its Chief Engineer's Department to hospitals which it no longer administered. I shall not dwell on the difficulties encountered during this period. It lasted only some nine months, and by March, 1949, control of the engineering services had passed completely into the hands of the new authorities.

### Engineering in the National Hospital Service

From the lateness of the Ministry's advices about engineering to the new authorities, and from the provisions of regulations made some six months earlier, apparently without regard to engineering considerations, there have followed two consequences, detrimental to the efficiency of engineering services to hospitals, which endure to this day.

(1) The Regulations provide that each Regional Board must delegate, among other things, the maintenance of hospital premises to Hospital Management Committees controlling individual hospitals or groups of hospitals, while the Regional Board is responsible for all new works. Consequently the Regional Engineer and the Hospitals Engineers are in separate compartments, the Regional Engineer being employed by the Regional Board and responsible to them for new works, while the Hospitals Engineer or, as he is now called, the Group Engineer, is employed by the Management Committee and responsible to them for operation and maintenance.

(2) The Ministry's advice about engineering authorised the appointment, in each Region, of a Regional Engineer as a principal officer directly responsible to the Regional Hospital Board and provided with assistant engineers. From the lateness of that advice, however, it resulted that when the Regional Boards received it they had already appointed, or were well on the way to appointing, their architects in accordance with much earlier advices, and many of them have not proceeded to the appointment of Regional Engineers, but are attempting to meet their engineering responsibilities by the appointment of assistant engineers in their Architects' Departments.

This is all wrong. The separation of the Group Engineer from the Regional Engineer takes no account of the many branches of mechanical and electrical engineering science and practice that contribute to the wide variety of engineering installations and appliances in a modern hospital. The day is long past when any one man could practise engineering in all its branches, and specialisation has become inevitable. The Group Engineer or the Engineer-in-Charge, a member, maybe, of this Institution, is the general practitioner in operation and maintenance. The Regional Engineer and his assistants, who should be corporate members of the Institution of Civil Engineers, the Institution of Mechanical Engineers, or the Institution of Electrical Engineers, have the different and more highly scientific technology that goes, among other things, to the practice and understanding of design. The close co-operation of these different, though related, skills is necessary for the best results. The present scheme, which puts barriers between them, cannot compare for efficiency with the unrestricted intercourse, for the good of the service, between engineers of all sorts of different training, experience and seniority which comes of their all being in one department, so that the special knowledge of each is readily available for any and every hospital, as was the case in the London County Council's engineering organisation. Whenever I have discussed these matters with some of my old friends among the Hospital Engineers, who have had experience of both schemes, I have found that they concur heartily in the view I have stated.

On the same principle this Institution advocated the appointment of Engineering Inspectors in its evidence before the Departmental Committee on Machinery and Engineering Staffs at Poor Law Institutions, which reported in 1909.† The Committee accepted the principle, and not only recommended the appointment of a fully qualified engineering inspector of the highest competence, with assistants, but stated that they regarded this as the most important of their recommendations.

Even as things stand, however, the Regional Engineer should have some concern with maintenance and operation. He is declared to be available for consultation on these matters, and, as Management Committees must submit proposals for any maintenance works estimated to cost more than £1000 for approval by the Regional Board, the Engineer presumably reports to the Board on such proposals. But these meagre provisions for co-ordination are stultified and frustrated when the most senior engineer available at Regional headquarters is a comparatively junior assistant in the Architect's Department. The educational standards for qualification as an architect do not require any grounding in the elements of natural science, without which no comprehension of the nature of engineering is possible. Supervision of the assistant engineer by an architect is at the best purely nominal. It may have a faint administrative flavour, but it can add nothing whatever to the engineering value of the assistant's work, and may, on the contrary, detract from such value as attaches to his junior status. Such a state of affairs can be no encouragement to Hospital Management Committees to seek consultation with regional headquarters in engineering matters.

Passing to the consideration of new works, which are particularly the concern of the Regional Board, there should, for buildings, be collaboration of architect and engineer on the equal footing of independent and direct responsibility to the Board, as the means of ensuring that structural engineering and provision for mechanical and electrical installations have due consideration in the design, and that

† (Cd. 4502, 1909)

subsequent operation and maintenance shall be truly economical.

As regards installations in new buildings, the Departmental Committee which I have already mentioned rejected evidence in support of a practice of placing the engineering as well as the building work in the hands of the architect, leaving him to employ a consulting engineer if he thought necessary. They recommended that the engineer should be employed directly and engaged jointly with the architect from the inception of the scheme. In view of engineering advances this is much more necessary now.

If Regional Boards wished to combine and co-ordinate engineering and building functions in one department, they would have been better advised to make the Regional Engineer the head of that department. For, whereas the architect's supervision of engineering is purely nominal, the engineer is no stranger to structural design and maintenance, and could very well undertake the building maintenance, possibly with a building surveyor's assistance. The architect's distinctive functions concerned with the planning and æsthetics of buildings have practically no application to maintenance, and consulting architects could be engaged for new building works. Whether or not they employ architects, however, the Regional Board's need for the services of Regional Engineers will not be disputed by anyone who has understanding of the two professions.

The present arrangements will inevitably conduce to an unnecessary burden on the country's restricted fuel resources by the installation of electrical heating devices, including electrically heated food trollies, without due consideration of real requirements and more economical alternatives, by lack of special attention to boiler-house efficiencies, and in other ways. Not long ago the Minister, speaking of possible economies in these directions, is reported to have pointed to the use that could be made of an average saving of £100 per hospital. I should be surprised if that figure were not a fraction only of the economies that could be effected, without any detriment to the services, if he were to see to the adoption of an organisation that would give real opportunity to the engineers, from which other benefits may also be confidently expected.

For example, I have just seen in the technical press criticism of an invitation by a Regional Hospital Board of tenders for electrical works at a hospital. The tenderers were required to design the scheme to fit certain structural alterations, and to supply drawings and a detailed specification of the materials and equipment. The critic very justly wonders how many contractors will go to the trouble of doing the Board's work, how many different schemes will be submitted, how many man-hours will be wasted by drawing-office staffs producing the drawings asked for by the Board, how much the materials and equipment specifications will vary, and how the Board will decide which is the best scheme. Obviously it would be in the national interest, and in the Board's own interest, if they employed their own Regional Engineer to design a single scheme and specification on which contractors could tender on a comparable basis (*Electrical Review*, page 522).

The National Health Service Act provides for the constitution of a Central Council to advise the Minister, and gives him power to vary the constitution of that Council and to constitute standing advisory committees thereto. I would suggest that he should arrange for one or more engineers to be members of that Central Council, or, at least, that he should constitute a standing advisory committee on engineering, and that he should make the appointments after consultation with the Institutions of Civil, Mechanical and Electrical Engineers.

# Capital Expenditure on Transport

## INSTITUTE OF TRANSPORT*

THE second field for increasing the efficiency of transport which it seems opportune to explore at this time is that of capital expenditure—a field outside the industry's control, although, of course, it is the duty of the industry to put Governments in possession of the facts.

No responsible person to-day will approach this problem solely on the basis that capital expenditure is justified if it shows an attractive commercial return to the industry in which it is incurred. The needs of the rearmament programme, of export and home consumption, including capital investment, are not to be denied. But without suggesting that the cake itself could be larger, we may doubt whether the slice of capital expenditure allowed to transport is as large as it should be—not merely in the industry's interest, but in the national interest. The simplified test is to determine in what sectors of the economy capital expenditure will increase national productivity to the greatest extent as soon as it has been spent, or at least very quickly. It is impossible to escape the suspicion that those who allocate the resources of materials and manpower which are available for capital improvement and development between different industries and purposes are inclined to regard expenditure on improved transport as if it were largely unproductive, and in the passenger field as if it were merely designed to increase the amenities of life for which the nation in its present circumstances must wait. But this is a glaring misconception. I am convinced that some of the most urgently needed capital expenditure on roads and railways, of benefit to the movement of both passengers and freight, could be shown to be highly productive, and (what is all-important in the present situation) more productive than much other capital investment now being allowed to take place in other industries. Without even raising the controversial, though legitimate, question whether, by the test of productivity, we are spending too much of our available resources on certain social services and housing, I believe it could be proved that the expenditure of, say, £10,000,000 on road improvements would produce a bigger and quicker dividend in the saving of man-hours, equipment and resources than an equal expenditure by almost any of the major industrial users of capital to-day. One well-known authority has expressed privately the conviction that such an investment on roads could be shown, if the facts were all properly established and marshalled, to yield a return in increased national productivity perhaps three times greater than the return obtained from the same capital spent on oil or steel or even electricity and about equal to the return from similar expenditure on coal mining. Yet the Government has put an almost complete ban on any capital investment on roads. It can only be assumed that the strength of the case has not been adequately brought home to it.

### Road Improvement

The Government's response to the cogent and restrained Report on London Traffic Congestion made to the Minister of Transport this year by the London and Home Counties Traffic Advisory Committee is profoundly disappointing, and a notable example of the failure to appreciate the fundamental part that transport plays in national life. The Committee, with a realistic sense of the competing claims for capital investment at this time, set aside for the present all the larger schemes costing more than £4,000,000 each, and recommended as a minimum immediate programme sixteen road improvements costing altogether under £20,000,000. It is true that the Minister has accepted many of the Committee's minor but useful palliatives not involving any material expenditure at all, and has appointed a Committee to study further a convincing recommendation that £5,000,000 should be spent at once on tackling the car-parking problem; but not a word of hope has been spoken that any part of the modest programme of road improvements is likely to receive any further attention at present. Yet it must be possible to make an overwhelming case for proceeding at once with all sixteen. The large savings possible, not only to the providers, but also to the users of public transport, by relieving street congestion and improving average speeds, is so apparent to those engaged in operating transport that we may have fallen into the mistake of thinking it equally self-evident to others. It may not be sufficient to rely on broad assertions and rough estimates such as the calculation that the operating cost of London Transport's central omnibuses alone would be reduced by over £2,000,000 a year if their average speed were raised by only 1 m.p.h., or that the overall annual loss from delays to traffic in London amounts to some £70,000,000 a year. We may be at fault in not having made for each specific scheme recommended more precise calculations of the diverse benefits, whether expressed in terms of man-hours or of money, which would accrue to the community not only through savings of resources, including vehicles, fuel and staff, both in public passenger transport and in freight transport, but through the further savings in passengers' time, fuel for private motoring, wear and tear on vehicles, policing, and so on, that will always arise from reduction of traffic delays.

I have referred, I hope excusably, to London; but, of course, in other cities and on busy main roads all over the country there must also be scores of opportunities for road improvements which would amply and immediately repay their cost, by eliminating delays and other forms of waste due to bottlenecks, level crossings, congested intersections, and the like. It is a sad reflection that in this country fly-over road junctions can be numbered on the fingers of one hand compared with many hundreds in the U.S.A. and in Germany. Yet in 1950 the density of motor vehicles per mile of road in this country was second only to Belgium among the countries of the world. It is a matter of common observation that we must be spending hardly enough to keep our roads in repair, let alone undertake improvements. It might come as a surprise to many outside this Institute that we can only find it possible to spend about two-thirds of 1 per cent of the national income on road improvements and maintenance. The United States and Canada spend twice as much. We ourselves spend a little bit more of the national income on newspapers or in the total amount staked in a year on football pools, and twenty times more on drink and tobacco, than we do on our roads.

There must be many cases, too, where uneconomic use of single-deck omnibuses and lengthy diversion of freight vehicles enforced by low bridges would be found to cost the country more in one year than the all-time cure.

### Railway Improvement

So much for road improvements. But capital expenditure on railways is also far too restricted. Even by the hardest economic tests it would pay the nation handsomely to divert more capital investment to the reduction of freight costs by rail. This country enjoys a natural advantage over most of its competitors which it would be foolish not to exploit to the full. Its geographical compactness makes possible a relatively low transport element in its total costs of production. I am told, for example, that of every £100 spent on buying steel, the transport costs of the raw materials and fuel used, and delivery costs, represent about £18 in the U.S.A., but only about £12 in Great Britain. This shows how great the economic value of low transport costs can be; but I am sure that my friends in British Railways would agree that the difference in our favour could be made much greater but for the planned restrictions on capital investment, which are in sharp contrast to the high priority accorded to restoration and modernisation of the railway systems in France and Holland, for

*Presidential Address, by A. B. B. Valentine (Member, London Transport Executive). Oct. 15th. Extract.

example. Of the present quota of British Railways over two-thirds has to be spent on track renewals and other civil engineering works essential to safe running even at existing sub-standard speeds. The margin left for real improvements must be trifling compared with the scope that must exist for increasing productivity—mainly, I suppose, by large schemes for extension, modernisation and possibly re-siting of marshalling yards, which take account of the major changes in dense flows of traffic in these post-war years; by the modernisation and mechanisation of freight terminals; by large-scale electrification schemes; and by wagon programmes which would accelerate the disappearance of the slow-moving grease-axlebox types, the adoption of a universal vacuum or compressed air braking system fitted to all wagons, and standardisation on types of the most economical capacity and design properly related to the needs of industry and trade. The desirability of such projects is not generally disputed, but, as with road improvements, the question I ask is whether their economic value to industry and to the community as a whole has been sufficiently worked out and well presented to secure the priority to which they are entitled.

Even rail improvements primarily required for passenger traffic may have an economic value, not always easy to quantify, far greater than is apparent at first sight. If I may be forgiven for reverting to London for an illustration, though illustrations are not lacking elsewhere, there is general agreement among experts that a new tube must be built from the north-east suburbs, relatively ill-served by rail, through King's Cross and Oxford Circus to Victoria with some outlet beyond to the south or south-west—substantially Route C of the London Plan Working Party's Report. But such a scheme is apt to be looked on as no more than a desirable improvement in the Londoner's standard of living and a convenience in equity due to the least well-served of its suburbs, neither of which we can afford at present. The certainty that the fares paid for travel on this tube will not equal the operating costs, including interest, adds to the feeling that it is a luxury which must be deferred till better times. This view, however, wholly disregards the far-reaching economic value of the scheme, which will never be reflected in its own financial results. The tube link from the Victoria area through the West End to King's Cross and St. Pancras must be of value to business and commerce. There will be an immense saving of wear and tear and of time to the passengers who use the new line both to and from the suburbs and in the central area, some part of which must add to their productivity, though some part admittedly only to their leisure. There will also be similar benefits on other underground routes now choked with traffic which the new tube will immediately relieve. But, in addition, the diversion of passenger traffic from surface travel to the tube will greatly relieve street congestion, with resultant widespread savings to street users of all kinds. The vehicles of British Road Services as well as London Transport omnibuses will be among the beneficiaries, but only a small part of the real gain will be reflected (and then not identified) in the Commission's accounts. It may well be that if all the economic benefits of such a tube could be measured, estimated and added up, the return would be large enough to justify its construction even in the conditions of to-day. At least, however, the example serves as another reminder that we in the transport industry must not assume that the economic case for capital expenditure on transport will be so readily accepted elsewhere without proof.

### Future Planning

In all the cases I have mentioned, and many others—not necessarily confined to road transport and railways—it is for the economists and statisticians in the industry, collaborating as required with bodies such as the Road Research Laboratory, to whose pioneer work in the field of road engineering and safety I should like to pay a tribute, to measure more thoroughly the benefits, both direct and indirect, accruing to the national economy from capital expenditure on specific schemes, whether for new works or re-equipment, designed to increase the efficiency of transport. Whitehall must not be blamed for blue-pencilling claims not adequately substantiated by the claimants. Yet nothing to-day is impairing the efficiency of transport more seriously than capital starvation.

I should like to add one footnote to this train of thought. Whatever success may attend our more determined efforts to secure in the national interest that a larger share of the nation's capital investment is devoted to transport, many of the most worthy projects, because of their very size, will still have to wait. Let us, however, not be induced by this knowledge to set them on one side for later study when prospects are more favourable. An unforeseen easement of international tension or a sharp change in our economic climate may come upon us suddenly—that has happened before. Let us bring the plans for the bigger schemes that matter most far enough forward so that we may be ready—with parliamentary powers in our pockets, if required—to start work upon them at once, if the opportunity comes unexpectedly upon us. Otherwise resources may be frittered away upon lesser projects that happen to be ready, instead of upon those that are most deserving and will ultimately benefit the country most, and the opportunity may pass—that, too, has happened before.

# Productivity in the Steel Founding Industry*

THIS report is based on information gathered by the Productivity Committee of the British Steel Founders' Association from the Association's members. It constitutes a review of progress in steel founding productivity since 1948 and examines the effects on productivity of the report of the Steel Founding Productivity Team, which visited the United States in 1949. Over half the Association's members, representing well over half the industry's total tonnage, have contributed to this report.

*Sales Policy.*—In the appendix to the Productivity report, reference was made to an address to the team by Mr. Stanley Holme, of the General Electric Company of America. He emphasised that in a successful business the three activities—engineering, production and selling—must keep in step. Several firms—although not a sufficient number to justify a broad generalisation being made—have shown that they realise how important an influence sales policy can exert in the interests of productive efficiency. Those firms which report along these lines are using sales policy to employ machines in place of unobtainable skilled workers, to reduce the variety of steel compositions and to obtain long production runs. An interesting note is struck by a member who insists that sales publicity is only a part of the framework of public relations, which stretch from the shop floor of the firm to the general public, within which the whole industry must live.

*Design.*—Replies here show that this is linked up with sales activities and emphasise how important it is that founder and customer should understand each other's ideas and difficulties, close co-operation between the two often leading to changes in design. Good design will cut subsequent costs and it is stressed that with increasing specialisation, the machining allowances formerly thought necessary can safely be reduced. Standardisation is being increasingly emphasised and some sections of the B.S.F.A. have succeeded in standardising certain castings, while one founder, by offering good deliveries for standard patterns but poor deliveries for fancy or frivolous modifications, has succeeded in having standardised designs accepted. Finally, one foundry "tied" to an engineering works has established one section working full time on problems of standardisation.

*Lay-out.*—A large number of important changes have taken place, ranging from one or two firms which have installed a new melting shop or new bays, to a general emphasis on better mechanised moulding, whether by moulding machines or by sand-slingers, and on improved efficiency and conditions in fettling shops. One typical example is that of a jobbing founder who has modernised the lay-out of his casting areas—this will speed up the turn-round of boxes and reduce sand movement. Other foundries have saved much loss of time by reorganising their pattern shops and improving their production control and one has cut down the movement of castings by centralising heat-treatment, burning-off and shot-blasting processes. It is clear that greater attention than before is being paid to those lay-out principles which have been long known and which the Productivity Report was by no means the first to emphasise.

*Equipment.*—Nearly all founders mention the installation of new equipment or the better use of existing plant over the last three years, despite the fact that many had already carried out extensive schemes of improvement and modernisation. The reports provide evidence that where equipment is already satisfactory, improvements in productivity have still been possible. One founder reports that he has improved productivity (measured in man-hours per ton) by 14 per cent on his sand-slinger, 47 per cent on machine moulding and 50 per cent on fettling. Many tell of a wide range of new equipment: one member has turned from open-hearth melting to electric arc furnaces; others have put in new machine-moulding installations or new sand-slingers, with better servicing—as by swing-jib cranes, roller conveyors and individual wind-rammers—and one speaks of his practice of supplying lifters in large quantities, sorted by sizes, and insists on the importance of straightening-machines for lifters. Several reports show large increases in productivity in moulding and fettling shops and one founder has doubled production since he introduced machine moulding. In the core shops more coreblowers are in successful use, new core stoves are reported and the use of light alloys for core plates and carrying boxes.

Several reports from B.S.F.A. members mention mechanical knockouts, flame-cutting machines, airless shotblasts and the use of crane magnets and real efforts are being made to tackle the dust problem. One founder has brought in an excavator to dig out his pits and others have installed new sand-mixing equipment. A mechanical loader for handling bulk materials is described and the prominent featuring of materials-handling equipment shows that its advantages are now realised throughout the industry. It is interesting to read that even a foundry engaged mostly on jobbing work has standardised moulding box sizes. Major re-equipment of pattern shops is also taking place in several other foundries.

Of all the steel-founding processes, steel melting has been the least affected by the prevalent re-equipment trends. This may be due to the shortage of electric power, which makes the installation of electric arc furnaces impracticable. Also the scarcity of scrap has prevented a general turnover from basic to acid melting, though two foundries report that they have done so and one has installed a transformer giving a very high power per tonnage rating for the melting units.

*Methods and Research.*—Only a general impression of trends under these headings can be given, for they are perhaps the most intimate

* Summary of Report issued by British Steel Founders' Association.

parts of a foundry's activity. Methods to speed operations which have been reported include the use of acid arc melting combined with carbometer testing and oxygen blow and this has reduced melting time by about 40 per cent tap to tap. Pattern changes have been speeded up to put short runs on machines and even for hand moulding, split and mounted patterns are coming into greater use. Many reports show that knock-off cores for quick removal of heads are being extensively used. More care is being taken to keep skilled men in skilled work and to service them efficiently.

One of the ways to produce better steel and cut down waste is by a reduction of refractory costs—one foundry has lowered these by 50 per cent—through better inspection, which often includes gamma-ray and magnetic crack detection and by the closest control of methods, sometimes even through special new methods departments and development sections. One founder has reduced his grinding costs by 40 per cent through close study of grinding-wheel usage. Increasing attention is also being directed to sand formulation to obtain better strip and consequent fettling economy. Green-sand work is increasing, with introduction of unit sand and several foundries are reaping benefits from the use of finer-grain sands. Economies are being sought in the use of exothermic feeding powders with short feeder heads, as was described in the Productivity Report.

Two members have sent technicians to the United States and one is using an American foundryman as consultant for a specific job. It is certain that many others have benefited from the visit to their works of American foundrymen. There is no doubt that at this time, when our members are being asked to make castings for machines which formerly came from the United States, more and more attention is being paid to improving the breed of our products.

*Personal Relations.*—It is a good thing to hear of improved working conditions and increased amenities throughout the industry, of schemes for apprentices, older entrants and supervisory staff, and publicity on the shop floor through the publication of productivity statistics and shop achievements. But none of these, nor incentive schemes, payment-by-results, or any other devices, are enough if there is not the knowledge throughout the foundry that all in it have one interest in common—the success of the firm. No member would claim to have the confidence of all his workpeople and one or two wrongly blame their workers or their workers' trade union leaders for their failure to obtain it. But blaming the other side will not help them—good leadership is the only way to a good spirit throughout a concern.

## Winter Freight Traffic

PLANS for dealing with freight traffic during the coming winter were announced at a Press conference last week by the British Transport Commission. Mr. F. A. Pope, a member of the Commission, who presided, explained that earlier this year the Railway and Road Haulage Executives made a detailed survey in order to forecast the volume of traffic—consisting mainly of rearmament materials, fuel, food, exports and products for home consumption—to be conveyed during the winter. Throughout the summer the two Executives had made all forward preparations within the resources available.

Mr. Pope said that traffic experts of the Railway Executive had re-examined the heavy flows of traffic, the facilities available to handle them, and the staff complement required, particularly in the industrial areas, where the difficulties arising mainly from the shortage of operating staff were most likely to occur. In order to ensure that the maximum tonnage of freight was carried by rail and road, joint discussions under the chairmanship of a member of the British Transport Commission had been taking place with the Federation of British Industries and the Association of British Chambers of Commerce. The outcome was that with the collaboration of those two bodies and the National Farmers' Union, a temporary nation-wide organisation was being set up to advise traders on their transport problems and in every district to enlist their closest co-operation. The aim was to enable the maximum effective use of the combined resources of British Transport to be made.

In each of the fifty-one railway districts a local joint committee, comprising the railway district commercial superintendent, the district manager of British Road Services, and representatives, as required, of the F.B.I., the Chambers of Commerce, and the N.F.U., would examine, as emergency arose, such questions as the re-routing of certain railway traffics, diversions to road, and any special measures to relieve congestion such as cutting down the number of wagons required to move a given quantity of traffic, obtaining better loading and speeding up the clearance of wagons. The local groups would thus support the efforts of the Railway and Road Haulage Executives to deal with traffic which had to pass through the difficult areas. The local groups would be kept posted of any changes in the transport situation which affect their locality and they would, in turn, be responsible for keeping industrialists, traders and farmers informed. Liaison at top level would be effected in London between leading representatives of the two Executives and the three trading and industrial organisations, meeting under British Transport Commission chairmanship.

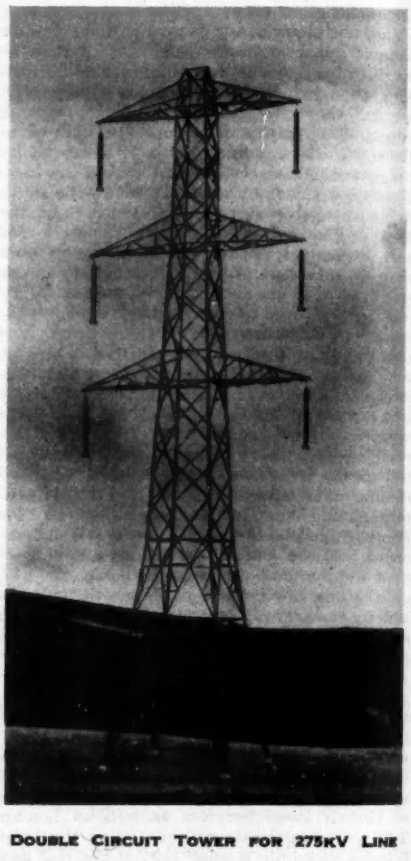
It was emphasised that this special liaison machinery set up for this winter was designed to reinforce the exceptional preparations which the two Executives had made, both individually and in concert, to minimise the effects of the labour shortage, to restore fluidity of freight movement during the summer, and to move the maximum tonnage during the winter. It did not in any way set up a duality of traffic control or operation, which remained the responsibility of the Transport Executives. As regards British Railways, Mr. Pope continued, freight capacity measured by the present ton-mile figures was 30 per cent over 1938, but it was calculated that the railways would be expected to lift about 5,000,000 tons more traffic than last winter, with about 5 per cent fewer staff. Nearly two-thirds of that increased load would be coal and the greater part of that concentrated in the weeks up to Christmas.

Some of the measures adopted by British Railways as part of the special campaign to keep essential freight traffic moving were outlined as follows:—up to 600 train crews a day made available for freight traffic working, through curtailment of summer passenger timetable; extensive planned diversions of freight traffic from congested routes to alternative routes, as was done during the war, including some never previously used for trunk traffic; intensive week-end freight working, nearly 450,000 tons of coal having been cleared each week-end recently; reorganisation of major flows of traffic to make "block" loads for destinations, or for distant sorting centres, in order to avoid intermediate marshalling yards affected by staff shortages. The traditional boundaries or exchange points of the former railway companies have been completely ignored in these diversions; widespread re-arrangement of engine and train-crew workings, to transfer duties from depots which are short of staff, to others which can provide them; transfer of fifty heavy freight engines from North-Eastern and Scottish Regions to Eastern, London Midland and Western Regions, thus enabling heavier trains to be worked; reorganisation of the locomotive workings on the East Coast main line between King's Cross, Grantham and York, thus yielding twenty-four more engine crews for freight working; assisted lodging schemes for staff prepared to transfer to Birmingham and London districts; the provision of additional railway hostel accommodation; campaign to avoid detention of wagons at goods terminals, including co-operation with traders in planning their loading and despatches and in prompt unloading of wagons.

Finally, it was explained that while British Railways had been carrying out these exceptional measures, the Road Haulage Executive had been making plans to deploy the total freight resources of British Road Services, with their 40,000 vehicles, so as to handle their share of the winter peak load. Full advantage would be taken of the great flexibility of road haulage operation. At all levels, close day-to-day contact with British Railways had been established to ensure that road vehicles could be quickly diverted to points of pressure. To overcome difficulties created by the short supply of new lorries to the home market, vehicles taken over that would not normally be kept in service were being specially repaired so as to provide additional carrying capacity. The whole of the Executive's repair resources, supplemented by those of outside repair contractors, had been mobilised for this purpose.

## 275kV Overhead Line Towers

THE British Electricity Authority has placed a contract with British Insulated Callender's Construction Company, Ltd., for the supply and erection of the 62 mile long section of line from Newcastle to Thirsk, forming part of the double circuit 275kV overhead line which will run from Clyde's Mill to West



DOUBLE CIRCUIT TOWER FOR 275KV LINE

Melton. Each phase of each circuit will comprise twin 0·175 square inch copper equivalent (37/110) S.C.A. conductors in horizontal formation, with a 12in spacing between the twin conductors. A single 0·175 square inch S.C.A. earth wire will be run above the phase conductors. The normal span will be 1000ft long with a maximum sag of 27·25ft at 122 deg. Fah. Normally, each suspension insulator string will consist of eighteen 11in diameter glass discs and will have an overall length of 124½in.

The towers for this line have been designed by Blaw Knox, Ltd., and a prototype D.2 tower, which has a height of 115ft 3in, was recently tested at the works of Painter Brothers, Ltd., Hereford. An interesting innovation in the construction of these towers will be the use of high tensile steel for a proportion of the sections and bolts. An impression of a double circuit tower as it will appear before the conductors have been run is given in the accompanying illustration.

# The Growth of Agricultural Engineering*

By F. E. ROWLAND, M.I.E.E.

WHEN surveying the present day range of farm machinery it is hard to believe that it is largely a development of the present century and although this is not the occasion for an historical survey, reference to a few outstanding achievements in farm machinery progress is relevant.

The forerunner of the plough was used in antiquity and modern development may be traced from 1653 with the introduction of the Hertfordshire and similar ploughs. A Dutch plough with a curved mouldboard was first imported into England in 1730 and the forerunner of the modern horse plough appeared in 1770, one of the first to be put into production being the Ransome Rutland plough. The invention of the first successful seed drill by Jethro Tull in 1731 marked another important advance in farm machinery. In reaping appliances the addition of a cradle to the scythe in about 1776, which saved no less than ten hours work per acre, was an outstanding achievement. The Rev. Patrick Bell's reaping machine, introduced in 1826, was another important innovation and was the forerunner of subsequent reapers and self-binders. From time immemorial the flail was used for threshing and the first machine, introduced in 1636, consisted of a number of mechanically revolving flails. Atkinson produced a peg-drum and concave thresher in 1760 and the first combined harvester-thresher was made in Australia in 1845. It was drawn by horses and stripped the grain from the standing crop. The forerunner of the modern combine was first manufactured in the U.S.A. in 1885 and combines were first introduced into England in 1927.

The beginning of the nineteenth century saw the introduction of steam power to farming and the turn of the century saw the appearance of the internal combustion engine, on which modern farm mechanisation is largely dependent. Electricity for lighting, heating and power in the farm buildings and home is now playing a major part in transforming the rural scene. The first medium weight tractor to appear in this country was Dan Albone's "Ivel" tractor in 1902. It was powered by a horizontally opposed, water-cooled, two-cylinder, four-stroke engine of 177 cubic inches swept volume, and had one forward and one reverse speed, all controls being hand operated. Now the farmer has taken to the air and thousands of aircraft are in use in many parts of the world for spraying crops and special machines have been developed for this purpose.

Future progress cannot be foreseen but may be as revolutionary as the advance from the primitive plough to the mounted reversible plough or from the flail to the combine harvester.

Great Britain has the most highly mechanised agriculture in the world and the rate of expansion is exemplified by the following figures :—

*Implements in Use in Great Britain*

| | 1942 | 1950 | Increase Per cent |
|---|---|---|---|
| Tractors ... ... ... | 116,830 | 332,200 | 184 |
| Mouldboard Ploughs—Tractor ... ... ... | 112,450 | 304,190 | 170 |
| Disc harrows ... ... | 33,840 | 82,140 | 143 |
| Cultivators or grubbers | 161,690 | 287,220 | 78 |
| Combine harvester-threshers ... ... ... | 1,000 | 10,490 | 949 |
| Potato spinners ... ... | 37,030 | 74,050 | 100 |
| Milking machines ... | 29,510 | 78,750 | 167 |

The expansion in the production of the agricultural engineering industry is also significant, particularly as if it were not for restrictions in raw materials the output would be greater.

In view of the rapid expansion in the industry and its increasing responsibility for feeding the nation, it is a matter of urgency to consider whether the resources which are being devoted to agricultural engineering research are now adequate. This applies to both national programmes and those of individual manufacturers.

*Production of the British Agricultural Engineering Industry*

| | 1946 £m. | 1950 £m. | Increase Per cent |
|---|---|---|---|
| Home ... ... ... ... | 20·2 | 41·9 | 101 |
| Export ... ... ... | 6·1 | 42·8 | 600 |
| Total ... ... ... ... | 26·3 | 84·7 | 222 |
| Export as per cent of total ... ... ... ... | 23·2 | 50·5 | 118 |
| | Tons | Tons | |
| Consumption of iron and steel ... ... ... | 142,400 | 385,000 | 172 |

Research is the lifeblood of engineering progress and it is essential that no economies in the national budget should be allowed to interfere with the progressive development of machinery to facilitate food production; in fact, under present world conditions, a substantial increase should be made in the funds available for this purpose. An adequate appropriation would be small compared with the vast sums which are being spent on armaments, with which food production ranks as an equal priority.

There is much to be done if agricultural machinery is to be fully utilised and production increased. In a recent speech, the Minister of Agriculture stated that the farming industry was now producing more than 40 per cent above its pre-war level. The extent to which this increase is due to the efforts of engineers is frequently questioned by economists but there is no doubt that without mechanisation these results could not have been achieved, neither could they be increased in the future. Whether further mechanisation can reduce production costs and also whether better use can be made of existing machinery, are two of the problems which must concern agricultural engineers deeply in the near future.

* Institution of British Agricultural Engineers. Presidential Address, October 16th, 1951.

# The Royal School of Mines

THIS month, the Royal School of Mines at South Kensington is celebrating the centenary of its foundation. It is now, of course, part of the University of London, and is one of the three constituent establishments of the Imperial College of Science and Technology. But when the school was started, on November 6, 1851, it was known as the "Government School of Mines and of Science Applied to the Arts."

Among those who took a leading part in the establishment of the school was Sir Henry Thomas De la Beche, F.R.S., who, although intended for a military career, took up geology and was elected a Fellow of the Geological Society at the age of twenty-one. In the early part of last century De la Beche put forward a proposal to make a fresh geological survey of the whole of Great Britain, and in 1832, in company with leading geologists of the time, he succeeded in gaining Government recognition of the project. But De la Beche also had a long-cherished desire to set up an establishment where facilities might be available for instruction in the arts related to the collection of mining and geological records. His efforts to that end resulted in the opening in 1851 of the Museum of Practical Geology in Jermyn Street, London, the building which was the first home of the Royal School of Mines. Its creation was a project which received the support of—among others—the Prince Consort, whom at the formal opening of the Museum, emphasised the great importance of mineral resources. When the Government School of Mines and of Science Applied to the Arts was opened it was announced that it was intended to give general instruction in science to those who might require elementary knowledge, but that the chief object of the institution was "to give practical direction to the course of study, so as to enable the student to enter with advantage upon the actual practice of mining, or of the arts which he may be called upon to conduct."

Four years after the school was started Sir Henry De la Beche died, and was succeeded by Sir Roderick Murchison, who became responsible for the activities of the School of Mines and of the Geological Survey. When Sir Roderick died in 1871 the association between these two bodies came to an end, and soon afterwards an Order in Council was made constituting the Education Department a part of the functions of the Privy Council Office, and ultimately the affairs of the School of Mines passed to the control of the Education Department. The removal of the school from Jermyn Street to South Kensington was completed by 1890. The next important stage in the history of the school was reached on July 8, 1907, when a Charter of Incorporation was granted, by which the Royal School of Mines, together with the Royal College of Science and the Central Technical College of the City and Guilds of London Institute became integral parts of the Imperial College of Science and Technology. The buildings which now house the Royal School of Mines in Prince Consort Road, South Kensington, were finally occupied in 1913.

In the immediately succeeding years further developments in the scope and usefulness of the school were made by the establishment of additional courses covering oil technology and mining geology. In the Royal School of Mines there are now departments of mining, metallurgy, mining geology, and oil technology, the number of students at present being 178, including nineteen who are engaged in post-graduate work. It should not be overlooked that in all departments of the school research is continuously in progress. In the metallurgy department, for example, through the generosity of the Nuffield Foundation, a special research group in extraction metallurgy has recently been set up. The training and experience gained by students of the Royal School of Mines fit them for a wide variety of services with mining, metallurgical and oil industries in all parts of the world. In fact, over the period of its 100 years, graduates from the school have played their part in such enterprises in every corner of the globe and have done much to maintain the reputation for probity, sound technical skill and judgment for which this country is justly famed.

# Gas Turbine Power Station

ONE of Britain's first gas turbine power stations, now being built in Hampshire by the Ministry of Supply's National Gas Turbine Establishment, is expected to be in operation by the end of next year. Although this 10,000kW station will be primarily an experimental plant for the study of operating techniques, it will generate power for the National Gas Turbine Establishment and, by means of a new system evolved by Ministry engineers, the waste heat given off by the plant will be used to heat the Establishment's buildings. The station may also make a contribution to the national grid. The installation consists of a low-pressure unit running at 2800 r.p.m., which in its capacity as a booster supplies compressed air to the main high-pressure turbine. This unit runs at 3000 r.p.m. and is connected to the alternator. The fuel for both units is to be either kerosene or gas oil.

# British Standards Institution

*All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.*

PIPE FLANGES FOR USE ON INTERNAL COMBUSTION ENGINES AND INSTALLATIONS

No. 1770 : 1951. This is a new standard for flanges for use on systems connected with internal combustion engines, such as coolant systems, exhaust and induction systems and oil pipe systems. It covers the general and detailed construction of oval, square and triangular pipe flanges for securing to pipes by screwing, brazing or welding. These flanges are not intended to be used on steam pressure work or other similar services. Tables of dimensions of flanges for use on a range of pipes ¼in to 4in nominal diameters are included. Details of materials are also given. Price 2s., post free.

# THE ENGINEER

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## PRODUCTIVITY IN STEEL FOUNDING

DURING March and April, 1949, the first productivity team to cross the Atlantic toured the United States for six weeks. It had been appointed by the British steel founding industry. In the following autumn it issued a forceful report, which attracted very wide interest and inspired a great deal of comment, and which undoubtedly influenced the organisation and method of reporting of every team that has since visited America. Possibly, indeed, it has coloured the views of members of all subsequent teams. That first team was not content to rest upon its laurels after its report was published. With the support of the British Steel Founders' Association, a means of further spreading the gospel was organised and higher productivity within the industry has since been energetically pursued. In particular, firms have been asked periodically to report upon results, and in this issue there appears an abstract of a report just issued that records what has been achieved up to date within the industry towards raising productivity.

The first reaction to that report is likely to be one of disappointment. So little seems to have been done in the two years since the original productivity report was issued. Yet such a reaction is certainly unfair. For it would be unreasonable to expect anything very startling to have happened. It is only large individual changes that can produce startling results amenable to an exciting presentation and such changes occur seldom. Real progress in improving productivity must be sought in the multiplication of minor changes, the total effect of which, though large, is difficult to present in words. When this report is re-examined it will be found that it does at least record progress over the whole field in which productivity can be improved, in sales policy (as influencing production policy), in design, in lay-out, equipment, methods, research and in personal relations. It is by no means easy to measure increases in productivity. For, since designs change as well as methods and since the distribution amongst types of product varies month by month and year by year, it is not enough merely to balance total output in tons against the man-hours of work involved. But the Association believes that one estimate at least gives some guidance as to the effects of improved productivity. Whereas, according to the Board of Trade index, the cost of certain industrial materials and manufactures has risen 120 to 140 per cent since 1939, the average selling price per ton of steel castings has risen only 83 per cent in the same period. There is no doubt in the minds of members of the British Steel Founders' Association that the visit of the team to the U.S.A. in 1949 provided a stimulus without which the improvement so recorded could not have been so large. Moreover, that stimulus continues to operate. One of the less easily foreseen beneficial consequences of the social contacts made during the visit of the team has turned out to be an enhanced flow of American foundrymen to our shores to see British foundries and discuss technical experiences with foundrymen here. Equally there has resulted an increase in the number of technical men from this country visiting America. So much are we convinced of the value of the free exchange of technical knowledge that we feel sure, had the team's visit had no greater consequences, it would still have been worth while.

But though progress has been made, it has not, in the opinions of many members of the Association, been made as fast as it might have been. Amongst managers and executives there have proved to be few to dispute the simple contention that higher material standards of living in this country can be obtained only through higher productivity. But there is still inertia to be overcome. For, though it may be estimated that a new design or a new method will prove advantageous, there can be no certainty upon the point until it has been tried. An adventurous spirit is thus needed amongst all concerned, workers as well as executives, in order to depart from the familiar and embark upon the new. That spirit is by no means always present. Moreover, the attitude taken up by the chief trade union concerned, the Amalgamated Union of Foundryworkers, has proved disappointing. For instance, the suggestion, implied in the original report rather than made as an outright recommendation, that a simpler wage structure would encourage higher productivity, has had to be dropped on the ground that it is not easy to simplify a structure built up upon many decades of negotiation, and certainly not possible unless there is more give-and-take upon both sides than there is at present. Indeed, the Union, after accepting the original report with some reserve, seems to have given little direct encouragement to methods of heightening productivity. It does not stand alone in taking that attitude. Trades unionism in the past has had as its objects the raising of wages and the improvement of conditions of work; and at least since the 'thirties it has had the further object of preventing unemployment amongst its members. In furthering that latter objective it has opposed upgrading of labour, thereby condemning a labourer always to be a labourer, and has proved often half-hearted in supporting labour-saving methods of production. Moreover, though many of its leaders now see that higher material standards of living can only be attained through higher productivity, the rank and file still tend to think in terms of the weight of the wage-packet alone. As Mr. Martin, leader of the team in America, has repeatedly stressed, the attainment of increased rates of productivity is the consequence of an attitude of mind. The desired attitude, the British Steel Founders' Association has found, is not well developed in the union. It must be hoped that continual preaching will in the end carry conviction to it.

## ELECTRICITY GENERATION AND TRANSMISSION

BY a rare coincidence two major surveys of the electricity supply industry in Great Britain made their appearance on the same day last week. One was the annual report of the British Electricity Authority and the fourteen area boards, reviewing their activities in the generation and distribution of electricity during 1950–51. The second survey was contained in Sir John Hacking's inaugural address as president of the Institution of Electrical Engineers. Extracts from both sources are reproduced elsewhere in this issue: the B.E.A. report, following the pattern of its predecessors, is a complete, factual, annual review which speaks for itself; Sir John's address ranged over a wider theme, dealing with trends in the generation and transmission of electricity, and taking us back nearly a quarter of a century to the "Electricals" presidential address by the late Sir Archibald Page. We were reminded that this country was then just embarking upon one of the major developments of the electricity supply industry—the establishment of the 132kV grid. Taking the story up twenty-four years later, Sir John, in his turn, was able to tell his audience something of the recent growth of the industry and of the consequent need for the 275kV grid which is now under construction.

To put matters in their true perspective Sir John began by making a brief but lucid comparison of the development of electricity supply in Britain and overseas. Taking the sales of energy from public and private sources as a criterion, he showed that Britain's achievements between 1939 and 1949 compare favourably with those of many

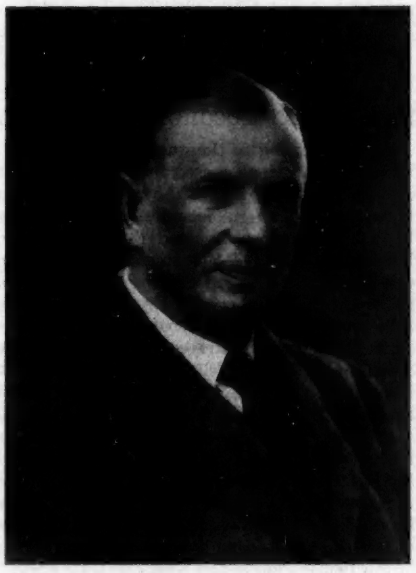
other countries. For, during that period the number of units sold in Britain increased by 64 per cent, a figure which was excelled only by Sweden's 76 per cent and the U.S.A.'s 117 per cent. That increase is all the more remarkable when it is recalled that Britain is almost alone amongst Western Europe in her inability to reduce her generating plant deficit to manageable proportions. It is true, of course, that some Continental countries, notably Italy and France, used Marshall Aid funds to buy and install generating plant from America. Through these funds Italy, for example, acquired, between 1948 and 1951, twelve steam and water turbo-generators with an aggregate capacity of 600MW. Such purchases were both legitimate and commendable and one cannot but wonder why it was that Britain was unable or unwilling to take Marshall Aid in a similar form. This omission is no doubt partly responsible for the fact that, until 1949 at least, France, Italy, Belgium, Norway, Sweden, Switzerland, and the U.S.A. outstripped Britain in the rate of installation of new plant. One unfortunate result of Britain's plant deficit is that she has been forced to keep in service old and relatively inefficient equipment—so much so that one-quarter of the total output in the year ended March 31, 1951, was generated at an average thermal efficiency as low as 16·3 per cent. Indeed, it is estimated that the installation of new plant according to programme would have made it possible to raise the average thermal efficiency from 21·5 to 22·5 per cent, with an annual saving of about 1½ million tons of coal.

Britain's shortage of generating plant and the need to use the existing capacity to the best advantage gives emphasis to the changing functions of the 132kV grid and the growing need for a superimposed 275kV system. As Sir John Hacking pointed out in his address, the original purpose of the 132kV grid was mainly to facilitate the pooling of generating plant within defined regions. Normally each region was to operate independently of the rest. Circuit links between adjacent regions were designed only for occasional use in emergencies or for simplifying maintenance. Pooling of plant on a national instead of a regional basis became necessary because of the unequal growth of load in the various regions. Accordingly interconnected operation of the regions was tried out in 1938 and has, since then, become the normal practice. Operation on that basis continued satisfactorily until the plant shortage in certain areas became acute and the grid was required to handle large power transfers to balance the deficit—a duty for which the system was not originally designed. Indeed, with only two circuits linking the north and south of the country the safe transfer of power in either direction is limited to 90MW, whereas the need is for a capacity to transfer at least 360MW to ensure the best use of available plant, with a minimum of load shedding. These considerations emphasise the need for strong reinforcement of the 132kV grid or for establishing a superimposed system at a higher voltage, such as 275kV. The only alternative, if it were practicable, would be to abandon national operation and revert to the original scheme of a number of independent operational regions. Sir John's address indicates, however, that regional working would require at least 5 per cent more installed generating plant with a capital cost far greater than that of the 275kV grid. But there is another compelling argument in favour of the superimposed system. For, quite apart from the effects of the short-term plant deficit, it is very likely that it will be cheaper to transmit electricity in bulk to an "importing" region like London, than to carry coal by rail from the Midlands to power stations situated in or near the load centres. That again was a point discussed by Sir John in an address that proved stimulating, not only by showing the activity of his own mind, but by indicating, too, how far ahead and how acutely the B.E.A. is thinking about its future development. Would that those developments could come to fruition earlier, that we might the sooner be rid of power cuts and power shortages! But such a hastening would need not only the devotion of increased manufacturing capacity to home equipment, but Governmental decisions upon the apportionment of national capital expenditure.

## Obituary

### VICTOR W. BONE

We have learned with regret of the death of Mr. Victor Bone, M.I.Mech.E., which occurred in a nursing home at Lincoln on Friday last, October 12th. Until his retirement, through ill-health, about two years ago, he was chairman and managing director of Ruston and Hornsby, Ltd., which company and its associates he had served throughout the whole of his active working years.



VICTOR W. BONE

Victor William Bone was born at Ipswich on February 17, 1883, and received his general education at Ipswich Middle School. In 1900 he began an apprenticeship with Ransomes, Sims and Jefferies, Ltd., studying, at the same time, at evening classes at the Ipswich Technical School. Upon completion of his apprenticeship Mr. Bone continued on the staff of Ransomes, Sims and Jefferies, Ltd., and subsequently spent four years, from 1907 to 1911, visiting European countries in the firm's interests. In 1911 he was appointed manager of the Ransomes' Parkside Works at Ipswich, a position which he held for the next four years. Mr. Bone then became manager of an aircraft works, established at Ipswich by his firm—principally under his direction—during the first world war. In 1917 he was appointed managing director of Ransomes, Sims and Jefferies, Ltd., taking particular responsibility for the activities of the Orwell works.

In 1922 Mr. Bone went to Lincoln as works director of Ruston and Hornsby, Ltd., and eight years later he was appointed managing director of its then newly-formed associate, Ruston-Bucyrus, Ltd. He continued in that office for fourteen years and then relinquished it to succeed the late Mr. G. R. Sharpley as managing director of the parent company. Mr. Bone was appointed chairman of Ruston and Hornsby, Ltd., in 1948, and it was a matter of keen regret among his colleagues and business associates that he was compelled, by failing health, to retire from that office a year after succeeding to it. Victor Bone saw his firm and its associates make considerable progress, progress that was in no small measure brought about by his able leadership. He will be affectionately remembered by those who knew him at Ipswich and Lincoln and by those who came into contact with him in the engineering and public works contracting industries.

### DR. ANTON FREDERIK PHILIPS

It is with deep regret that we record the death, on Sunday, October 7th, at his home in Eindhoven, Holland, of Dr. Anton Frederik Philips, president of the board of directors of the N.V. Philips Gloeilampenfabrieken Eindhoven. By his death, at the age of seventy-seven, the Netherlands has lost an outstanding industrialist and one of the pioneers in the electrical and electronics industries. It may be recalled that the original firm of Philips and Company was founded on May 15, 1891, by the late Mr. B. F. D. Philips and his eldest son, Dr. Ir Gerard L. F. Philips. After a few years Anton Philips, Gerard's younger brother, joined the firm and from the first he interested himself principally in its commercial development. From small beginnings, with only some thirty workmen, the lamp manufacturing business prospered and when in 1922 Dr. Ir Gerard Philips retired, the Philips factories were employing about 5500 people. In the period 1896 to 1922 Anton Philips travelled widely and did much to extend and widen the scope of the Philips undertaking. In 1922 he was called upon to take entire charge of the firm and his unusual energy and ability enabled him to build up and extend the firm. Its progress was assisted by the early foundation of a purely scientific physical laboratory for research and development work. During the difficult years of the second world war, when the Eindhoven and other European works were under enemy occupation, Dr. Anton Philips remained at the head of the firm and from the U.S.A. he continued to lead the organisation which conducted the affairs of the Philips concern.

In the war years about one-fifth of the factories in Eindhoven were destroyed by air bombardment and many Eindhoven people lost their lives in the resistance movement and in concentration camps. Under Dr. Anton Phillips's inspired leadership, however, by 1946 the firm had increased its level of production to that of 1939. At the time of his death Dr. Philips had the satisfaction of knowing that the firm which he had so faithfully served for fifty-five years was employing more than 90,000 workmen and staff in its Eindhoven and other branch

undertakings in Holland and its factories in no less than twenty-six different countries.

His outstanding work in promoting the prosperity of the Netherlands was recognised by his fellow countrymen. He received, in 1928, the Honorary Doctor Degree of the Commercial University of Rotterdam, The Order of the Netherlands Lion and a special gold medal for Energy and Ingenuity.

During the past few months Dr. Philips's health had failed somewhat, but in May he was able to see on the television screen the unveiling of a statue of himself in the centre of the town of Eindhoven, by the Mayor of Eindhoven, as part of the Jubilee Celebrations of the great organisation, the building up of which had formed his life's work.

He will long be remembered not only in his native land but in many other countries, as a business man of forceful and enterprising character, whose broad vision and kindness of heart endeared him to a wide circle of friends.

## Letters to the Editor

*We do not hold ourselves responsible for the opinions of our correspondents*

### THE CLOSING OF BRANCH LINES

SIR,—I read with surprise Mr. Francis's letter regarding the closing of branch lines, published in THE ENGINEER for September 21st. Mr. Francis wonders why British Railways do not make use of railcars, and in this connection I would point out that no less than thirty-eight diesel railcars have been in service on the G.W.R. since 1934, two of these being parcel cars, four of them being twin coaches, in which there are buffet and lavatory facilities, and two being single cars with buffet and lavatory facilities. These cars were used with great advantage in pre-nationalisation days, but now that the order has changed, it will be interesting to see if continued use is made of these excellent cars on branch lines.

LEWIS T. PERKINS

Wolverhampton,
October 5th.

### "BRITANNIA" LOCOMOTIVE PROWESS

SIR,—May I be forgiven if I say that I imagine a note of fulsomeness in your editorial on this subject? It is as though it had been written under some compulsion to find cause for praise for the "Britannia" class "Pacifics." These engines have not as yet equalled the regular top-rank performances of pre-war British "Pacifics" of comparable size; in no way have they exceeded normal expectations for engines of their dimensions, and so "prowess" is not a word that would have occurred to me in connection with them.

It is mentioned, apparently with approbation, that they have "a notably low water consumption," but compared with what? In other places we find the boilers of Great Western locomotives commended because they boil more water per pound of coal than do many other boilers. Variations in this water rate are easily explained by the amount of superheat given to the steam and if it were specially important to save water that could be done by adopting a very high superheat. Is it claimed that the water rate per pound of coal for "Britannias" is much lower than what would be expected from the temperature of steam leaving the superheater?

It is mentioned that the new "Pacifics" are running on routes dissimilar in physical characteristics, but surely that is only to be expected of a type announced to have been designed for wide route availability. Of the routes actually specified the only one markedly different from the others is the Western Region main line west of Newton Abbot, and there a "Pacific" is certainly not the ideal type. If such an engine can do the work already regularly undertaken by much smaller ones, that is hardly a matter for surprise; if the "Pacific" consumes less coal (never mind the water) that is excellent, but it would be interesting to know whether it does. The haulage of 350 tons at 39 m.p.h. from Plymouth to Penzance may or may not be described as hard running, but let us not forget that Great Western 4–6–0s can do it.

The most notable feature of the working of these 95-ton "Pacifics" in Cornwall is the fact that the Saltash bridge is allowed to take them, whereas in Great Western days it was held to be a bar even to the 82-ton 2–8–0s of the "4700" class. How many similar weight restrictions are being modulated in the interest of route availability of class "7 Pacifics"?

If it is indeed true that enginemen give the "Pacifics" a "warm welcome," that is only a natural reaction to an engine so much oversize for its job that it can do it even when handled in the most slapdash manner.

The use of "Pacifics" on 250-ton trains in East Anglia is something to be deplored rather than reported as a commendable modern development as even the most difficult present-day schedules are well within the proved capacity of much smaller engines.

Already in Great Britain there are at least three times as many "Pacifics" as are needed even on the basis of pre-war traffic requirements. Only if it is accepted that coal and maintenance will become much worse in the future, so that enfeeblement of locomotives is normal, can the building of more "Pacifics" be justified. They are a sign of the times and a depressing one.

W. A. TUPLIN, D.Sc., M.I.Mech.E.

Sheffield, October 15th.

### PRESENT-DAY LOCOMOTIVE WORKING

SIR,—Referring to the query from Mr. E. B. Parker the accident caused by the detachment of a balance weight from the reversing motion of a Great Eastern locomotive occurred in 1882. The engines involved were two of Mr. Massey Bromley's 4–2–2 singles with 7ft 6in driving wheels. An up express hauled by No. 603 was travelling between Ely and Cambridge at a good speed when the balance weight came adrift and, striking the corner of one of the coaches of the train, fell on to the down track where it caused the derailment of a down express. This train was hauled by No. 609, a similar engine to No. 603. Consequent on this mishap the balance weights were removed and replaced by coil springs. An account of this accident is published in Volume I of the newly issued reprint in book form of E. L. Ahrons's classic series "Locomotive and Train Working in the Latter Part of the Nineteenth Century."

F. A. S. BROWN

London, S.W.1,
October 6th.

## Technical Reports

*A Study of the Voussoir Arch.* National Building Studies Research Paper No. 11. By A. J. S. Pippard and L. Chitty. London: H.M. Stationery Office. Price 2s. 6d.—The main results of the investigation on the voussoir arch by the two authors were published in 1936. The present report, publication of which has been greatly delayed, brings together all the information made available by the original investigations as revised in the light of further large-scale tests. The report gives a historical review, a chapter on the mechanics of the work, an analysis of arch behaviour, and two chapters on experimental work devoted to static tests and repeated load tests respectively. All this work is summed up in a conclusion, and an extensive bibliography is given.

## Literature

*The Gas Turbine Manual.* By R. J. WELSH and G. WALLER. Temple Press, Ltd., Bowling Green Lane, London, E.C.1. Price 25s.

THIS is a well-ordered and well-written survey of gas turbine technology with stress almost exclusively on the industrial side. It covers in an interesting manner basic theory, behaviour of components and applications before leading up to descriptions of actual plants. An account is given of the work of probably every firm in the world interested in gas turbines derived from the similar reviews which have appeared from time to time in *The Oil Engine and Gas Turbine*. The information is also tabulated in an appendix.

Those familiar with the forceful exposition of one of the authors will not expect impersonal or lukewarm opinions—which rarely make interesting reading. They will allow for rather less than justice being sometimes done to the opposite side. Nevertheless, in a subject where ingenuous notions are not unusual the present work is distinguished by a practical balanced point of view founded on a former oil engine background. For instance, the authors well appreciate that steam is still in a virtually unassailable position for large power stations in this country so long as the gas turbine cannot burn coal.

A closer familiarity with large-scale power production, and particularly the gas turbine developments before the war, would have avoided their making a number of minor historical errors. For instance, the Neuchatel gas turbine was not supplied in 1938, as stated on page 4. It was on test at Baden in August, 1939, and later was on view at the Swiss National Exhibition in Zürich. Similarly, the rotary regenerator was not "invented by Ritz in Germany during the war," but by Frederick Ljungström in Sweden about 1917. It was already in large-scale commercial use in power stations in the 1920s, in contrast to the gas turbine field, where it has not yet been employed commercially for excellent reasons. Incidentally, the statement that there is a clear distinction between "regenerative" and "recuperative" in this country or elsewhere is a perfection only in the minds of the authors, since we cannot rewrite history in the form of old gas turbine literature in which "regenerator" is freely used where the authors would now use "recuperator." Moreover, the regenerative concept has been familiar too long in a wider sense, e.g., "regenerative feed heating," to be now so narrowly confined.

A minor irritation in the book is to find neither Parsons's nor Reynolds's names correctly spelt. A somewhat similar untidiness affects abbreviations. The authors appear to be undecided between the B.Th.U. and the C.H.U.; the former sometimes appears as B.T.U., which may be confusing, since officially it means Board of Trade unit—now the kWh, which the authors write kW-hr and quote as 3413 B.Th.U. instead of 3412.

### BOOKS RECEIVED

*Creep of Metals.* By L. A. Rotherham. London The Institute of Physics, 47, Belgrave Square, S.W.1. Price 15s.

*Watchmakers' and Clockmakers' Encyclopædic Dictionary.* By Donald de Carle. London: N.A.G. Press, Ltd., 226, Latymer Court, Hammersmith, W.6. Price 30s.

*Metallurgical Abstracts (General and Non-Ferrous), Volume 16, 1948–49.* Edited by S. C. Guillan. London: Institute of Metals, 4, Grosvenor Gardens, S.W.1. Price 60s.

# Electricity Generation and Transmission in Great Britain

## INSTITUTION OF ELECTRICAL ENGINEERS

### No. I

THE new president of the Institution of Electrical Engineers, Sir John Hacking, delivered his inaugural address at a meeting of the Institution in Savoy Place, London, W.C.2, on Thursday, October 11th. Abstracts from Sir John's address are reproduced herewith.

It is natural that my address should deal with some aspects of the work of the electricity supply industry and I propose to review the more important current developments in the field of generation and main transmission. But before proceeding with this review it may be useful to provide a background of foreign experience against which British achievements over the past few years can be judged.

#### Supply of Energy

The growth in public supply in Britain during the ten-year period 1939–49 represented an increase of 83 per cent, a figure exceeded only by Switzerland, Sweden and the United States. The figure refers only to the public supply, but in many countries a considerable proportion of the national electricity supply is provided from private industrial power stations direct to the works which they serve. A better picture of the rate of growth in the various countries is therefore given by Table 1, which shows the total energy supplied from both public and private systems.

Table I—*Energy Supplied to Consumers from Public and Private Systems*—1939 *and* 1949

| Country | Amount, kWh | | Increase | |
|---|---|---|---|---|
| | 1939 | 1949 | kWh | Per-centage |
| | $\times 10^9$ | $\times 10^9$ | $\times 10^9$ | |
| U.S.A. ... ... ... | 139·5 | 302·7 | 163·2 | 117 |
| Sweden ... ... ... | 7·9 | 13·9 | 6·0 | 76 |
| Great Britain ... | 29·0(*a*) | 47·6(*b*) | 18·6 | 64 |
| Switzerland ... ... | 5·0 | 8·0 | 3·0 | 60 |
| France ... ... ... | 17·6 | 26·6 | 9·0 | 51(*c*) |
| Netherlands ... ... | 3·6 | 5·4 | 1·8 | 50 |
| Belgium ... ... | 5·3 | 7·7 | 2·4 | 45 |
| Norway... ... ... | 9·6 | 13·7 | 4·1 | 43 |
| Italy ... ... ... | 15·8 | 17·2 | 1·4 | 9(*d*) |
| Western Germany | Not available | 32·3 | — | (*e*) |

*Source :* UNIPEDE statistics.

*Notes :*

(*a*) Includes an estimate of $6·4 \times 10^9$kWh from private generation.

(*b*) Includes an estimate of $6·2 \times 10^9$kWh from private generation.

(*c*) It is estimated that this figure would have been about 56 per cent had 1949 not been a year of subnormal rainfall and hence subnormal output from hydro-electric generating stations.

(*d*) It is estimated that this figure would have been about 20 per cent had 1949 not been a year of subnormal rainfall and hence subnormal output from hydro-electric generating stations.

(*e*) No accurate figure is available, but the increase in supplies from public and private systems in what is now Western Germany is believed to have been of the order of 15 per cent between 1939 and 1949.

From this Table it will be seen that the true growth in total electricity supply in Britain between 1939 and 1949 was about 64 per cent, a figure similar to that for Switzerland and not much greater than the figures of 45–50 per cent for the Netherlands, France, Norway and Belgium, though substantially greater than those for Italy and Western Germany. The British 64 per cent was, however, rather less than Sweden's 76 per cent and considerably less than the figure of 117 per cent for the United States.

In order to indicate the relative growth of requirements of different classes of consumer, Table II has been prepared. This shows the proportions in which the figures of total consumption given in Table I were divided between traction, industry and other consumers.

It is unfortunate that a more complete analysis of consumption by classes is not available. However, it will be seen from Table II that there has been a marked increase in most countries in the proportion of the total consumption attributable to the group "agriculture, shops and offices, domestic, public lighting and small power." The proportional consumption in 1949 of this group in Britain at 40 per cent of the total was, for that year, amongst the highest in any of the countries listed and was similar to the figure of 40·2 per cent for the United States, though lower than that of 44·1 per cent for Switzerland. It was very much greater than the figures of 23·6 per cent for Western Germany, 20 per cent for France, 19·7 per cent for Italy and 14·6 per cent for Belgium.

Table II—*Proportion of Total Supply from Public and Private Systems Taken by the Various Consumer Groups in* 1939 *and* 1949*

| Country | Year | Traction | Industry | Agriculture, shops and offices, domestic, public lighting and small power | Total consumption, kWh |
|---|---|---|---|---|---|
| | | Per cent | Per cent | Per cent | $\times 10^9$ |
| Belgium ... ... ... | 1939 | 4·4 | 83·3 | 12·3 | 5,327 |
| | 1949 | 4·0 | 81·4 | 14·6 | 7,714 |
| France ... ... ... ... | 1939 | 5·3 | 77·6 | 17·1 | 17,588 |
| | 1949 | 6·3 | 73·7 | 20·0 | 26,565 |
| Great Britain ... ... | 1939 | 4·3 | 64·9 | 30·8 | 29,001 |
| | 1949 | 3·0 | 57·0 | 40·0 | 47,574 |
| Italy ... ... ... ... | 1939 | | Not available | | |
| | 1949 | 8·5 | 71·8 | 19·7 | 17,207 |
| Netherlands ... ... ... | 1939 | 6·8 | 67·5 | 25·7 | 3,580 |
| | 1949 | 4·2 | 64·9 | 30·9 | 5,437 |
| Norway... ... ... ... | 1939 | 1·1 | 74·7 | 24·2 | 9,588 |
| | 1949 | 1·3 | 63·9 | 34·8 | 13,695 |
| Sweden ... ... ... ... | 1939 | 9·0 | 75·6 | 15·4 | 7,861 |
| | 1949 | 9·1 | 62·7 | 28·2 | 13,918 |
| Switzerland ... ... ... | 1939 | 6·0 | 57·6 | 36·4 | 4,951 |
| | 1949 | 6·3 | 49·6 | 44·1 | 8,017 |
| U.S.A. ... ... ... ... | 1939 | 4·1 | 60·8 | 35·1 | 139,468 |
| | 1949 | 2·0 | 57·8 | 40·2 | 302,664 |
| Western Germany ... | 1939 | | Not available | | |
| | 1949 | 3·3 | 73·1 | 23·6 | 32,271 |

*Source :* UNIPEDE statistics.

* Only in the case of the 1949 figures for Norway and Sweden is any analysis of the total supplies from private systems available. In all other cases it has been assumed that the whole of such supplies is given to "industry."

While the figures which have been quoted give a picture of the rate of growth of energy supply in Britain as compared with other countries, there still remains the question of the relative absolute rates of energy supply in the different countries. This is shown for 1949—the latest year for which international statistics are at present available—in Table III.

It will be seen from this Table that total energy supplies per head of population in Britain are rather greater than in the principal industrial countries of Western Europe but substantially less than in Switzerland, the Scandinavian countries and the United States. Amongst the reasons for the high figures for Switzerland and the Scandinavian countries are the lack of indigeneous fuel and the considerable development of the electro-chemical and electro-metallurgical industries based on cheap water-power, with correspondingly heavy consumption of electricity. For instance, over two-fifths of the total consumption in Norway during 1949 was for these industries.

#### Supply of Power

So far reference has been made only to supplies of energy (kWh) as distinct from supplies of power (kW). In this country it is the supply of power at time of peak load rather than the supply of energy over the year which has been, in recent times, the most serious problem. Here the position of Britain is not so favourable as that of other European countries. Shortly after the end of the second world war several of the Western European countries, such as Italy, France and Western Germany, as well as Britain, had serious power deficits amounting to as much as 500–1500MW at time of peak load. By the winter of 1950–51, however, it appears that in all parts of the mainland of Western Europe—except South Holland—these deficits had been eliminated or reduced to negligible proportions. Meanwhile, in Britain the position has grown worse instead of better, despite the efforts which have been made both to commission more plant and to reduce the peak load. This is illustrated by Fig. 1, which shows the average weekday surplus or deficit of generating plant available at time of daily peak demand during the months of December and January for the winters 1941–42 to 1950–51.

Table III—*Energy Supplied to Consumers from Public and Private Systems per Head of Population*, 1949

| Country | Supplied from the public system | Supplied from public and private systems |
|---|---|---|
| | kWh | kWh |
| Norway ... ... ... | 2340 | 4280 |
| U.S.A.... ... ... ... | 1670 | 2030 |
| Sweden ... ... ... | 1500(*a*) | 1910 |
| Switzerland ... ... | 1350 | 1710 |
| Great Britain ... ... | 811 | 933(*b*) |
| Belgium ... ... ... | 502 | 897 |
| Western Germany ... | 439 | 681 |
| France... ... ... ... | 488(*c*) | 643(*c*) |
| Netherlands ... ... | 415 | 544 |
| Italy ... ... ... ... | 291(*d*) | 372(*d*) |

*Source :* UNIPEDE statistics.

*Notes :*

(*a*) Excludes an estimate of $3·0 \times 10^9$kWh from private generation.

(*b*) Includes an estimate of $6·2 \times 10^9$kWh from private generation.

(*c*) The figures for France would probably have been about 4 per cent higher if 1949 had been a year of normal rainfall.

(*d*) The figures for Italy would probably have been about 10 per cent higher if 1949 had been a year of normal rainfall.

Why is it that the power deficits in this

country have persisted while in other countries they have not? Has the rate of construction of new generating plant been less rapid here than elsewhere? It is difficult to assess this since the data are not always complete or on exactly the same basis, but the rates shown in Fig. 2 are believed to be substantially accurate and comparable.

From this it appears that the rate of construction after the end of the war lagged in Britain, as compared with other countries, until about 1948; but that since then it has accelerated until it is now level with what is being achieved elsewhere. Britain's slow start is perhaps not unexpected in view of the restriction on the programming of new generating plant which had necessarily to be imposed after Dunkirk and which produced its full effect only some years later. Furthermore, there is one factor which has undoubtedly been of assistance to some Continental countries. This is the use which they have made of Marshall Aid funds to purchase American power plant. Thus, for instance, in France an American 100MW set was installed at the Gennevilliers power station in Paris, and the expansion of the industrial power plants was also to some extent aided from this source: an example of the latter is the installation of two 60MW American generating sets at the Déchy station of the French coal mines. Similarly, a proportion of the Marshall Aid allocated to Italy was used to increase the sources of electricity production in that country: the purchase in the United States of twelve thermal and hydro turbo-generators with a total capacity of 600MW, together with boiler plant of a capacity of 120MW, was financed from these funds between 1948 and 1951, and it is expected that further similar purchases will be made. No part of the dollar funds made available under the Marshall Plan to the United Kingdom were used to assist in overcoming our serious power shortage.

I would have liked to include here some reference to maximum demands and load factors, but unfortunately the statistics available for the different countries are inadequate for a proper comparison to be made.

## Thermal Efficiency

It is not the only object of the supply industry to make available adequate supplies of energy and peak-load power. It is also necessary to do this with maximum economy and efficiency. In this respect a comparison of British and oversea achievements is not easy, as much of the data required are not available and the operating conditions in the different countries vary greatly. For instance, many of the European countries depend to a large extent—in some cases almost entirely—on water power, the thermal stations being used only at certain seasons of the year or for peak-load operation. Thus it is not surprising to find that the thermal efficiency of the coal-fired stations of Electricité de France—which derives about half its supplies from water-power plant—was only 17·3 per cent in 1948 and 17·7 per cent in 1949, as against corresponding figures of 21 per cent and 21·3 per cent for the stations of the British Electricity Authority.

A comparison with the United States, where only about one-quarter of the total output is from water power, would be more useful; but overall figures of thermal efficiency are not available, as the published national statistics refer only to fuel consumption per kilowatt-hour sent out from power stations and the average calorific value of the coal burned in these stations is not known. However, more complete data are available for a group of 200 base-load stations located fairly representatively over the whole of the United States. In 1947—the latest year for which information is available—the coal burned by this group represented 72 per cent of the total tonnage consumed in public utility stations in the United States, and had a weighted average

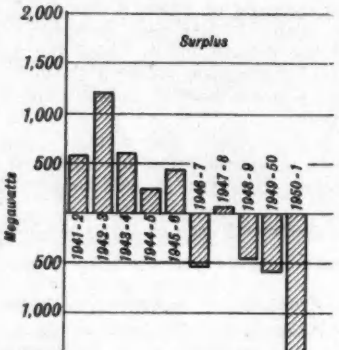
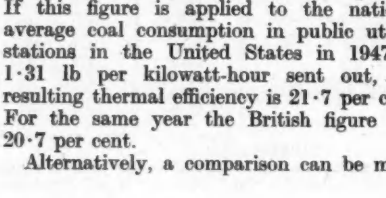



**Fig. 1**—*Average Weekday Plant Load Conditions at Time of Daily Peak Demand During December and January (British System)*

calorific value of 11,980 B.Th.U. per lb. If this figure is applied to the national average coal consumption in public utility stations in the United States in 1947 of 1·31 lb per kilowatt-hour sent out, the resulting thermal efficiency is 21·7 per cent. For the same year the British figure was 20·7 per cent.

Alternatively, a comparison can be made




Sources: UNIPEDE statistics, Edison Electric Institute *Bulletin*, OEEC statistics, Central Statistical Office *Bulletin*, and others.

**Fig. 2**—*Increase in Installed Capacity, 1946–50*

between the thermal efficiency of this group of 200 American base-load stations and a roughly corresponding group of sixty British stations. This comparison shows that in 1947 the thermal efficiency of the American group was 23·3 per cent, and of the British group 22·4 per cent. In comparing these figures the appreciably higher load factor of the American systems should be borne in mind. This is indicated by the number of kilowatt-hours sent out per kilowatt of installed capacity, which in 1947 amounted to 5379kWh for the American group of base-load stations as compared with 3815 kWh for the British group.

In 1950 the national average coal consumption in the United States had fallen to 1·19 lb per kilowatt-hour sent out. In the absence of other information it may perhaps be permissible, for the purpose of a rough estimate, to apply the same figure for calorific value as in 1947. The resulting thermal efficiency in 1950 would then be 23·9 per cent, which may be compared with the corresponding British figure of 21·5 per cent. It thus appears that between 1947 and 1950 the improvement in thermal efficiency in America was much greater than in Britain.

It is not hard to find a reason for this difference. For in Britain, owing to the enforced retention in service of old plant and to the long running hours required from that plant because of the virtual removal by load shedding of the shorter-term peaks, the average thermal efficiency of generation of a quarter of the total output in the year ended March 31, 1951, was as low as 16·3 per cent. It is estimated that, had it been possible to commission new plant according to programme and so to be in a position to meet demands in full, the output of the lower-efficiency plant would have been substantially reduced and the overall average thermal efficiency increased from 21·5 per cent to 22·5 per cent, thus saving about 1½ million tons of coal in the year. Had it been possible, in addition, to replace by new plant 1000MW of the old plant of lowest efficiency, the average thermal efficiency would have been increased to 23 per cent, with a further saving of some 800,000 tons of coal in the year. This brings me to the subject of development of new generating plant.

## Generation Developments

*Programmes of New Plant.*—Of the plant programmed for the five years 1946–50, only some 47 per cent had been commissioned by the end of the period. I shall not discuss the reasons for the failure to achieve a greater proportion of the programme, or the measures which have been and are being taken to improve the rate of commissioning. But I should like to point out that the numbers of turbo-alternators and boilers comprising our present and future programmes are considerably less than the numbers that were being installed over twenty years ago. For example, in the year 1929 a total installation of 759MW required fifty-four turbo-alternators and ninety-nine boilers. With the larger units, the 1950 installation of 1034MW required only twenty-three generating sets and forty-five boilers; while the 1956 programme, with an installation of 1903MW, will require thirty-five sets and forty-three boilers. I suggest that, with the increasing capacity of units, the overall effort on the part of all concerned in carrying out the generating plant programmes is not necessarily proportional to the size of the programmes; and I am convinced that, provided the necessary materials and labour can be made available, the programmes which are now in hand and even larger future programmes are well within the capacity of the manufacturers and of the design staffs of the Authority and the consulting engineers. But the rearmament programme is at present seriously increasing the difficulties in obtaining materials. It is essential that these difficulties should be removed if the

generating plant programmes are to be achieved.

*Plant Capacities.*—Although the early programmes sanctioned after the war included a proportion of plants which were repetitions of existing designs, much thought was given to the new standards which should be adopted having regard to the urgent need for rationalisation of design. While the largest single straight-condensing turbo-alternator unit operating at 3000 r.p.m. in this country before the war was 42MW, larger back-pressure sets at the higher speed of 3600 r.p.m. were operating in the United States. Discussions with manufacturers indicated that there would be no difficulty in building straight condensing sets up to 60MW at 3000 r.p.m., and this was economically desirable. The position was not so clear with regard to boilers and at first it was deemed necessary to limit capacities to some 360k-lb per hour, for which rating either fusion-welded or forged drums could be used for designs involving only one or two drums. A number of stations were therefore planned with 60MW turbo-alternators each associated with two 360k-lb per hour boilers. With the installation of several fusion-welding plants of increased size and the associated heavy plate-bending presses, larger capacities became practicable, thus permitting adoption of the desirable unit lay-out—one boiler, one set—for capacities up to 60MW, and later even up to 100MW. More than one-third of the total 13,000MW programme is being installed with the unit boiler arrangement. This comprises a total of ninety-seven individual sets and boilers, including fifty of 60MW capacity and five of 100MW capacity.

Over 70 per cent of the total programme will employ pulverised fuel firing. This is at present the only practicable method of firing the large boilers required in the unit arrangement.

*Steam Cycles.*—In the effort to rationalise, three general standard conditions have been adopted, and in the present programmes some 10,400MW of the plant has been ordered on the following cycles :—

(*a*) 3207MW comprising 96 turbines and 160 boilers, at 600 lb per square inch, 850 deg. Fah., 340 deg. Fah. temperature.

(*b*) 6315MW, comprising 108 turbines and 181 boilers at 900 lb per square inch, 900 deg. Fah, 385 deg. Fah. feed temperature.

(*c*) 880MW, comprising 12 turbines and 12 boilers, at 1500 lb per square inch, 1050 deg. Fah., 400 deg. to 430 deg. Fah. feed temperature.

Although the reheat cycle had its origin in Great Britain, it has had a greater application in the United States. The complication resulting from the use of multiple boilers, coupled with the high efficiencies obtainable with non-reheat cycles at higher temperatures, caused a halt in the development in both countries. Since large unit boilers became practicable, it has more recently been applied on a large scale in the United States, where 124 machines using reheat, with a total capacity of 14,000MW, are either in operation or programmed.

The adoption of reheat with high pressure and temperature introduces difficulty in design. As the coal qualities used for electricity generation in Great Britain are, in general, inferior to those in the United States, it has been deemed advisable to be cautious in the interests of reliability. But recent studies have indicated that, with the location of the primary superheater sections in the radiant heat zone, or the use of tilting pulverised fuel burners, both of which give better control of steam temperature, unit boilers for 100MW sets using reheat are now feasible. One of the new stations has been designed for these conditions, and others are being planned. In all cases, however, it is proposed to limit the temperatures to just below 1000 deg. Fah. to enable a freer use of ferritic alloys in the boiler.

*Gas Turbines.*—With the possibility of using higher temperatures, the gas turbine is potentially capable of greater efficiency than the straight steam cycle, and the development of this type of plant is being encouraged. It is expected that three gas turbine plants will be commissioned this year—two, of 15MW capacity each, for the British Electricity Authority, and one, of 12·5MW capacity, for the North of Scotland Hydro-Electric Board. The two former are open-cycle plants, designed for initial operation with distillate oils. These plants are regarded partly as experimental, and it is hoped later to use crude oils or solid fuels as suitable combustor designs are developed.

Although with higher temperatures the gas turbine might well reach an efficiency of 40 per cent or more, its only practical applications at the moment are those using oil as fuel. In this country, the future of the gas turbine may depend on the possibility of using our natural fuel—coal—and much research is taking place at various manufacturers' works on methods of doing this.

*Other Potential Thermal Developments.*—In a variation of the normal closed gas cycle, it has been proposed to use steam as the working fluid with a large proportion working over about the same pressure ratio as in the closed gas cycle, and to obtain about the same temperature ratio by diverting the balance of the steam, after it has been passed through the gas turbine and exhaust heat exchanger, to a low-pressure condensing turbine driving an additional generator. The condensate from the condensing turbine would be reintroduced in spray form to the main turbine and compressor circuit, either ahead of a number of compressors working in series or at their individual suction branches. The efficiency of the cycle will be influenced to a considerable extent by that of the steam compressor, and separate experiments are taking place on this item of equipment before proceeding with further development.

Great interest is also being taken in the possibility of combining the gas and steam cycles. The air passed through an open cycle gas turbine is much in excess of that required for the combustion of the fuel, with the result that most of the oxygen is left in the exhaust gases. It has been proposed that the exhaust flow from the turbine should be used as the combustion air supply to a steam boiler, which, in turn, would supply a normal turbine. Many combinations have been developed, in some of which the exhaust flow from the gas turbine is also used for interstage reheating of the steam turbine and for feed water heating.

Other schemes envisage using the open-cycle gas turbo-compressor system as a means of obtaining pressurised combustion in the boiler furnace, as originally exemplified by the Velox boiler. With pressurised combustion the heat transmission rates through the boiler surfaces are materially increased, so enabling the dimensions of the boiler to be reduced. Overall efficiencies of around 40 per cent might be obtained with these methods, but the practical development depends on correctly proportioning the gas turbine and boiler components.

(*To be continued*)

# Brazing and Welding Copper and Aluminium for Electrical Connections

By E. V. BEATSON, B.Sc. (Eng.), A.M.I.E.E.*

No. I

THE chief limitations of soldered joints are to be found in their relatively low mechanical strength, particularly at elevated temperatures of the order of 100 deg. Cent. and upwards. An additional disadvantage, which applies particularly to quantity production of electrical equipment, is that, in spite of considerable ingenuity in mechanisation, most joints have still to be made by hand, and reliance must be placed on the skill of the operator. As regards aluminium, the difficulty of soldering by conventional soldering techniques and without corrosive fluxes, is one of the main reasons for the continued restriction in its use for electrical components.

For these reasons various other methods, which can be loosely classified under the headings of brazing or welding, have been applied to, or developed for, specific applications. It is evident that none of them have the same scope for ready and immediate use in such a wide field as that covered by soldering. Nevertheless, most, if not all, of them will be more widely used in the future, given close collaboration between designers and process engineers in the early stages of a design, and the intelligent development of each application as an individual problem.

* Joseph Lucas, Limited, Birmingham

## Brazing

Brazing may conveniently be defined as the joining of metals at temperatures well below their melting point, by the addition of a different metal or alloy, which, when molten, usually tends to be drawn by capillary attraction into, and right through, the entire joint. The soft solders are, of course, specifically excluded from this category, but by common consent silver soldering or "hard soldering" is now generally classified as a brazing process.

The common brazing metals which can be used on copper or copper alloy and for joining these to steel are given in Table I. Groups 1 and 3 can be used for brazing copper alloys to each other or to steel; both these groups require active fluxes, which must, of course, be completely removed after making the joint to prevent subsequent corrosion. Group 2 alloys are for copper only and require no flux, as the phosphorus in the alloys act as a deoxidiser, thereby performing the function of a flux. Joints made with these alloys in Group 2 are of high strength, and though not quite so ductile as those made with the Group 1 silver brazing alloys, they are satisfactory for most requirements and are very widely used. The brazing alloys in Group 4 are for aluminium, and require special fluxes

which are extremely active and must be completely removed, otherwise corrosion will take place in service.

*Methods of Heating.*—For brazing electrical joints the heat is usually applied by torch or by electrical resistance heating. The torch employs flames of coal gas and compressed air, oxy-coal gas or occasionally oxy-acetylene. Resistance heating may be by incandescent carbon electrodes or by

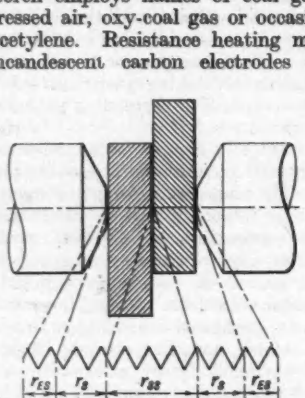



FIG. 1—WORK RESISTANCE IN SPOT WELDING OR RESISTANCE BRAZING

direct interfacial resistance heating in a machine of the normal butt, spot or projection welder variety. Furnace brazing is rarely used except for certain special subassemblies, such as in the manufacture of contacts, mainly because of the undesirability in almost all instances of heating the whole assembly. High-frequency induction heating has the great advantage of being extremely localised, but is relatively inefficient on copper and aluminium.

Before considering various examples, it is advisable to study some of the characteristics of the heating methods and of the brazing alloys, particularly in relation to their effect on finished assemblies, insulation, &c. It will be appreciated that, for good brazing, as for soldering, the entire joint surfaces of both components must be heated to the temperature required by the particular brazing alloy.

*Torch Heating.*—In general, the torch does not provide a very rapid and localised method of heating, and there is considerable spread of heat away from the joint area, which is often likely to damage most kinds of insulation and even protective finishes on adjacent components. The extent of heat spread will be greatest with the low-temperature gas-air flame and least with oxy-acetylene.

*Carbon Resistance Heating.*—With the carbon resistance method, heating is achieved in two ways: primarily in the carbon electrodes themselves, which quickly become incandescent, whereupon the heat is transferred by conduction to the components; and to a much lesser degree in those portions of the components themselves, which actually carry the heating current between the two carbons. Obviously, the best results are obtained when the carbons can be placed very close to the joint and on either side of it, so as to give rapid and even heating of both components, with the minimum of heat spread away from the joint. Where the component design lends itself to this method, heating is usually more rapid than with the torch and brazing can be accomplished in a matter of seconds.

*Direct Interfacial Resistance Heating.*—In this method the components are held between electrodes similar to those used in resistance welding. They are made of high conductivity copper alloys or copper-tungsten alloys, and occasionally of molybdenum or tungsten. Because of the relatively lower resistances compared with carbon, the heat required for brazing must be generated mainly in the work itself by its own internal resistance to the passage of the brazing current. Fig. 1, which indicates the way in which this work resistance is constituted in spot welding, may be taken as applying in principle to most interfacial-resistance brazing. The resistance $R_w$ is made up mainly of the interfacial contact resistance between the components, and, to a lesser extent, of the internal resistance of each component and the contact resistance between each component and its electrode. Naturally, the work resistance $R_w$ is of a very low order particularly when brazing copper and copper alloys and, in consequence, very much heavier currents are required than when using the carbon resistance method. These currents may vary between, say, 2000A and 30,000A, depending on the size and nature of the work. Very high currents and short times are always used, to reduce to a minimum the wasteful dissipation of heat from the joint area by the high-heat-conductivity copper components; heating times are usually less than one second, and rarely above two seconds. These conditions, assisted by the rapid chilling action of the heavy electrodes of good heat-conductivity material, are characteristic of this method, particularly as applied to electrical joints; they provide localised heat just where it is required. As will be seen from some of the later illustrations, joints have been brazed in this way at temperatures between 650 deg. and 900 deg. Cent., without disturbing insulation such as enamel, bakelite, rubber, P.V.C. or cotton as near as ⅛in to the joint.

Another point of importance in resistance brazing is the effect of flux on the electrodes, whether carbon or copper alloy. In most applications, the electrode faces show a tendency to become contaminated with flux residue which progressively reduces the current and, hence, the heat. The trouble is, perhaps, more serious in the case of direct interfacial-resistance brazing where lower voltages and higher currents are used, and conditions are more critical. For this reason, the method is invariably confined to those combinations of metals and brazing alloys where a flux is unnecessary. Until recently, virtually the only such combination was copper and the phosphorus-bearing, self-fluxing alloys in group 2, Table I. To this group are now added the recent developments, described later, in which one of several selected coatings is deposited on the components specifically to provide a brazing metal in such a way that, under interfacial-resistance heating conditions, no flux is needed.

TABLE I.—*Brazing Alloys*

| Group | Brazing Metal | Melting Temperature, deg. Cent. Approx. | Application |
|---|---|---|---|
| 1 | Silver-brazing alloys ... ... ... | 620–850 | Copper, copper alloys, brass, steels |
| 2 | Phosphorus-silver-copper alloys ... | 690–750 | Copper, and some copper-rich alloys |
| 3 | Brasses and bronze-alloys ... ... ... | 850–950 | Steels, copper occasionally |
| 4 | Aluminium-silicon alloys, with additions | 570–630 | Aluminium and some aluminium alloys |

FIG. 2—TORCH BRAZING OF SQUIRREL-CAGE ROTORS

FIG. 3—CARBON RESISTANCE BRAZING OF COPPER-CONSTANTAN THERMOCOUPLE HEADS

*Torch Brazing Copper to Copper.*—A well-known application is in the manufacture of rotors for squirrel-cage motors. The copper rotor bars are brazed to copper end

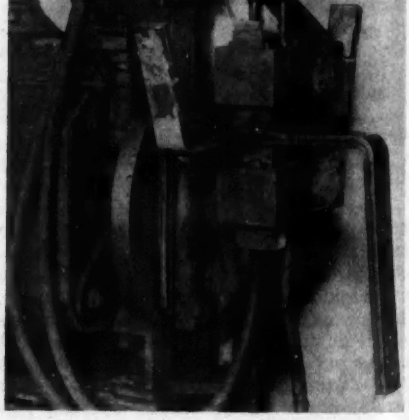


FIG. 4—CARBON-RESISTANCE BRAZING OF COPPER TRANSFORMER CONNECTIONS

plates or end rings, using one of the silver-phosphorus-copper self-fluxing alloys of group 2. The flame is usually oxy-coal-gas or occasionally oxy-acetylene; in the latter instance a slightly oxidising flame should be used, and the envelope of the flame should play on the work, not the hot cone as in welding. Small rotors are shown in Fig. 2 being brazed in this way with a phosphorus-bearing, low-silver alloy developed by Johnson Matthey and Co., Ltd. This alloy has the very low liquidus of 694 deg. Cent.; though not so ductile as some of the higher silver-content alloys in this group, it has ample strength and ductility for this purpose, and is, of course, more economical. In the application illustrated, the brazing alloy is fed in to the joint by hand.

Larger rotors, in which the rectangular bars are brought out to lie on the outer circumference of heavy end rings, are also brazed in the same manner. Here the rotor is mounted horizontally with the shaft running in vee-blocks. The flame can be fixed to play on one spot, leaving both hands free to apply the brazing alloy and turn the rotor unless the latter operation has also been made automatic.

*Carbon Resistance Brazing.*—The photograph reproduced in Fig. 3 illustrates the

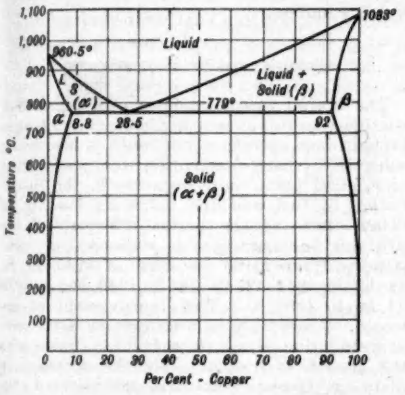



FIG. 5—SILVER-COPPER EQUILIBRIUM DIAGRAM

application of this method to the brazing of copper-constantan thermocouple heads at the works of Sangamo Weston, Ltd. The carbons are brought horizontally, by pedal operation, into light spring contact with opposite sides of the work. Further pressure on the pedal switches on the current and heating begins, the flux and brazing alloys being added by hand as required. In this instance, the low melting point (approximately 630 deg. Cent.) silver-brazing alloy to B.S.S. 206, Grade C, in group 1, is used in conjunction with its active fluoride-base flux. While it is by no means essential in all instances, the use of some form of fume extractor is an advantage when using these fluxes.

An excellent example of heavier work being brazed by this method of heating is shown in Fig. 4. This is the arrangement used for brazing copper transformer connections at the Rugby Works of the British Thomson-Houston Company, Ltd. In this instance the electrodes are mounted vertically and the water cooling of the heavy electrode blocks is clearly shown. Here the brazing alloy is not fed into the joint by hand, as in Fig. 3, but is preplaced in the form of a thin shim wrapped round the central copper strip forming the joint. The alloy is one of the higher silver-content, phosphorus-silver-copper alloys of group 2, so that no flux is required.

*Direct Interfacial-Resistance Brazing.*—Because of the heavy currents needed to generate sufficient heat, by this method, in the low-resistance metals such as copper and copper alloys it has been applied mainly to relatively light assemblies. It is, of course, in light engineering that the method has the greatest appeal, as large quantities of small assemblies lend themselves very readily to the same kind of high-speed automatic production usually associated with the resistance spot, projection or butt welders used for resistance brazing. Two factors can be accepted as axiomatic in these applications: no flux should be used, and the

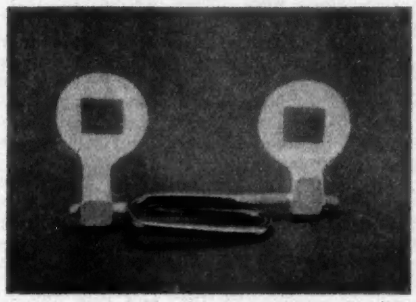


FIG. 6—SILVER-PLATED BRASS EYELETS RESISTANCE BRAZED TO ENAMELLED COPPER WIRE

brazing alloy should always be preplaced at the joint in some convenient manner.

The self-fluxing phosphorus-bearing alloys of group 2 meet these conditions when preplaced in the form of rings, shims or washers. A very interesting application which is being developed both in Great Britain and in the United States, is the resistance brazing of armature conductors to commutator segments of heavy-duty d.c. motors, but full details of the process are not available.

Another method recently developed for preplacing the brazing medium in a very convenient form is that of providing, by electrodeposition, dipping or similar means, a suitable metallic coating on one or both components. Some of the various combinations of metals and coating, which have been developed or adapted specially for the

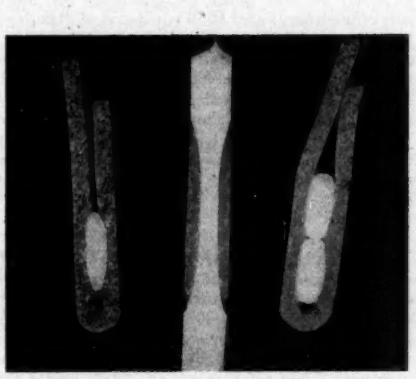


FIG. 7—SECTIONS THROUGH JOINTS SIMILAR TO FIG. 6

resistance brazing of electrical connections, are described below.

*Silver-Coating Brazing of Copper and Copper Alloys.*—The principles and some early applications of this process have been described elsewhere.[1] In brief, silver and copper have the property of forming a series of alloys of melting points lower than those of either pure silver (960 deg. Cent.) or of copper (1083 deg. Cent.), as illustrated in the equilibrium diagram, Fig. 5. It was already known that if silver-plated copper components were heated in a furnace to just over 780 deg. Cent., the eutectic alloy was formed, and this alloy effectively brazed the components together provided that oxidation was prevented by a reducing atmosphere.

When it was tried to heat similarly plated components locally in a welding machine it was found that a braze could be achieved in much the same way, but without the use of a flux or even a reducing atmosphere. This fact is probably explained by the extremely short time of heating, which produces very little oxidation, and the disrupting effect of the electrode pressure. It is unlikely that, in this short heating time, a braze would result unless the silver coating actually melted at some point on the interface, i.e., at such a low temperature as 780 deg. Cent.; but such local melting of the silver is quite easily achieved in interfacial-resistance heating without actually melting the components themselves.

It has been found possible in this way to produce sound joints between copper conductors, of either round wire or flexible, and copper or brass strip. The photograph, Fig. 6, shows two joints between enamelled copper wire of 16 S.W.G. and silver-plated brass strip components. The enamel is

FIG. 8—MICROGRAPH OF PORTION OF JOINT SHOWN IN FIGS. 6 AND 7

removed locally from the wires before making the joint, but the localised nature of the brazing heat is such that this insulation is not damaged near the joint. In some joints of this kind two wires are brazed simultaneously to one strip. Longitudinal and transverse sections taken through these single and double-wire joints (shown in Fig. 7, about three times full size) indicate the nature of the joints, and the degree of deformation of the components, which produces excellent mechanical "keying" quite apart from the brazing. Fig. 8 shows at high magnification (×300 approximately) a portion of one of these sections; the thickness of the actual brazing alloy layer, just visible, is approximately 0·0001in.

Connections have also been made in this way between light copper flexibles and phosphor-bronze, the flexible being laid directly on to the silver-plated phosphor-bronze strip, and spot brazed to it in a standard type spot welding machine. On this type of connection, the rubber, P.V.C. or other insulation is completely undisturbed by the very localised brazing heat.

*(To be continued)*

[1] E. V. Beatson, "Brazing and Welding of Coated Materials," *Welding*, June, 1950.

BRITISH VALVE MANUFACTURERS' ASSOCIATION.—Mr. N. P. Newman, managing director of Newman, Hender and Co., Ltd., has been elected chairman of the British Valve Manufacturers' Association. He succeeds Mr. E. Bruce Ball, managing director of Glenfield and Kennedy, Ltd., who has served as the Association's chairman for the past three years.

# The British Electricity Authority's Annual Report

IN a Journal note last week we briefly recorded some of the salient points from the third annual report of the British Electricity Authority. In the following paragraphs we reproduce extracts forming a general summary of the report, which deals with the operations of the B.E.A. during the year ended March 31st last, and discusses electricity progress and future requirements.

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Over 55,500 million units of electricity were generated at the power stations owned by the Authority. This total was 13·1 per cent more than in the previous year, a third more than was generated by the electricity supply industry in 1947–48, the year before nationalisation, and well above double the amount generated in 1938–39. At the end of the year there were over 13 million consumers—being nearly 450,000 more than a year before, 1,360,000 more than at vesting day, three years before, and over 3 million more than in 1939.

Sales of electricity to consumers exceeded 46,500 million units. This total was 12·3 per cent more than in the previous year, almost a third more than in 1947–48, the year before nationalisation, and much more than double the sales in 1938–39. Half the sales were to industry, a third to domestic consumers, and an eighth to commercial consumers. Industrial consumption was 11·8 per cent more than in the previous year, domestic 12 per cent more and commercial 16·7 per cent more.

The average price received for electricity was 1·181d. per unit, which was 1·6 per cent below the 1949–50 average, 4·2 per cent above that of 1947–48, and 12·5 per cent above that of 1938–39. The increase of 12·5 per cent in the average price per unit of electricity as compared with pre-war, was very much less than the price increases of nearly all other commodities, and certainly very much less than the price increases which the Authority and the Area Boards had to pay for coal, machinery, building construction, and equipment and materials of all kinds. Indeed, for electricity sold to "domestic, commercial and small power" consumers, the 1950–51 average price of 1·463d. per unit was 8·3 per cent below the pre-war average.

The combined revenues of the Authority and the Area Boards exceeded by £6,327,177 the amount of their combined outgoings properly chargeable to revenue account. This surplus, together with the surpluses for 1948–49 and 1949–50, give a total of £17,882,097 for the three years since vesting day.

### Generation and Main Transmission

*Generating Capacity and Programmes.*—At March 31, 1951, the Authority owned 289 power stations, with a total installed generating plant capacity of 14,592MW and a total output capacity with all plant in service of 13,156MW. Compared with a year earlier, the net increase in output capacity was 819MW, or 6·6 per cent. Because of the shortage of generating plant it is still necessary to retain in operation many generating sets and boilers which are old, small and expensive to operate. Over a third of the steam-driven generating sets, representing 13·2 per cent of the total installed capacity, and over a third of the boilers, representing 12·6 per cent of the total evaporative capacity, were twenty-five years old or more. Nearly half the sets, representing 9·7 per cent of the total installed capacity, had individual capacities of less than 8MW, as compared with present-day standards of 30MW, 60MW and upwards. More than a third of the boilers, representing 8·1 per cent of the total evaporative capacity, had individual capacities of less than 40,000 lb per hour, as compared with the 250,000–550,000 range for most of the boilers under construction.

The new generating set and boiler capacity brought into service was distributed among twenty-five power stations and gave an additional output capacity of 918,000kW (sent out), which was much more than in any previous year. The stations included three large new ones—Croydon B, Agecroft H.P. (Salford), and Poole—which were opened during the year. Plant having an output capacity of some 60MW (sent out), with an average age of thirty-four years for generating sets and thirty-five years for boilers, was shut down to make room for new plant or because the plant had become unserviceable. In addition, some plant was acquired or recommissioned, and some plant ratings were revised.

The survey of potential sites for power stations was continued. In order to give more time for dealing with the difficulties of finding suitable sites and obtaining authority to construct stations, the planning period was extended by the adoption of the provisional plant programmes for 1957 and 1958. These programmes, together with those for 1955 (supplementary), 1956, 1959 and 1960, include provision for transmission over the future 275kV system of gradually increasing quantities of power from stations situated in the developing coalfields of the East Midlands and Yorkshire, to the coal importing areas of Lancashire, Merseyside, London and the Southern Counties.

Power station capital contracts approved by the Authority during the year amounted to some £85 million, as compared with £68 million in 1949–50. It was estimated that, at the price levels ruling in the autumn of 1950, the average capital cost of the new power stations and extensions of power stations included in the 1955 (supplementary) and 1956 plant programmes would be approximately £50 per kilowatt (installed). This is about three times as much as the pre-war figure.

Further progress was made in the co-ordination of lay-out and general design of power stations, and the design and development of generating plant received much attention. Three-quarters of the generating capacity included in the plant programmes for 1955 (supplementary) and 1956 consisted of standard 30MW and 60MW generating sets. The higher-capacity plant included four turbo-alternator sets of 100MW capacity, each supplied with steam from a single boiler. Two will operate at a steam pressure at the turbine stop valve of 1500 lb per square inch at 1050 deg. Fah. The exact steam conditions for the other two were not finally settled, but one will have a reheat cycle.

### The Grid System

At March 31, 1951, the Authority's grid system comprised 4506 route-miles (6117 circuit-miles) of main transmission lines and cables, of which 4037 operated at 132kV and the remainder at 66kV or lower voltages. During 1950–51 there was a net increase of 284 route-miles at 132kV and a net decrease of 1202 route-miles at 66kV or less, the latter arising from the arrangements being made for the transfer of ownership of certain lines as between the Authority and Area Boards. At the end of the year there were 271 grid substations, with a total transformer capacity of 16,092MVA; they included sixteen new substations.

An outline scheme for the 275kV grid, to meet requirements up to 1960, was prepared, and detailed studies were made for the development of the first stage, to be completed by 1955. The new system is designed to provide adequate interconnection capacity between the various parts of the country and for bulk transmission from coal exporting to coal importing areas.

The major transmission works put in hand during the year included 265 route-miles of 132kV overhead line and approximately 371 route-miles of double-circuit 275kV overhead line. The latter comprises sections of the new higher-voltage grid between West Melton (Sheffield) and Clyde's Mill (Glasgow) and between Tilbury and Elstree. The total value of contracts placed during the year was £10·7 million.

Extensive reinforcement of the system is required to meet the rapidly growing load and to maintain secure supplies to consumers, and twenty-three new points of supply to Area Boards were agreed. It was estimated that the provision of these additional supply points would show a saving to the Authority and Area Boards of approximately £1,750,000, as compared with the costs which would have been incurred if the requirements had been met by developing existing points of supply under pre-vesting conditions. It is estimated that savings aggregating £4,650,000 will result from such schemes approved in the three years since vesting day. Considerable extension of the system is necessary, also, for the connection of new power stations, and five major schemes were approved.

The estimated cost of the sections of the 275kV grid approved for construction was approximately £7·75 million. The approximate cost of all transmission schemes approved during the year, including also new points of supply, the reinforcement of existing connections and connections to power stations, was £24 million.

### Generation of Electricity

The overall thermal efficiency of generation continues to rise as new high-efficiency plant is brought into operation, but much is also being achieved by careful attention to the condition of existing plant, improvements in the distribution of fuel and the optimum loading of plant. The average thermal efficiency of the Authority's steam power stations has risen steadily from 20·86 per cent in 1947–48, to 21·15 in 1948–49, 21·33 in 1949–50, and to 21·54 in 1950–51. The improvement shown would, of course, have been greater if the rate of installation of new plant had kept pace with the growth of demand; for the shortage of plant in recent years has necessitated the increased loading of plant of relatively low efficiency.

Average works costs per unit of electricity sent out from the steam stations increased from 0·4872d. in 1949–50 to 0·4894d. in 1950–51, or by 0·5 per cent. As a result of the improved efficiency of generation, heat consumption per unit sent out fell by 1·0 per cent, but as there was a rise of 3·3 per cent in the average cost of heat, the fuel cost per unit was 2·3 per cent higher. Costs per unit of repairs and maintenance fell by 8·9 per cent and costs per unit of operation salaries and wages by 5·8 per cent.

There has been a continuous increase in the loading of power station plant, the average load per kilowatt of maximum output capacity having risen from 41·2 per cent in 1947–48 to 47·1 per cent in 1950–51. At all times the highest practicable load is placed on plant having the lowest fuel costs; as the system load increases more units have to be generated by plant having higher fuel costs, and this has an adverse effect on average works costs per unit.

The Authority continued to be the largest individual purchasers of coal in Great Britain. They consumed in their power stations in 1950–51 some 32¼ million tons of coal and also 850,000 tons of coke and 80,000 tons of oil and other fuels. The total fuel consumption of 33·61 million tons was 11·5 per cent (3·48 million tons) more than in 1949–50, and the corresponding increase in electricity generated was 13·1 per cent, the difference between the two percentages being due to the improvements in efficiency of generation and, to a small extent, in calorific value of fuel. The average delivered cost per ton of British coal to the power stations was 13·6 per cent higher in March, 1951, than in April, 1950, due to

increases in the pithead price of coal and in transport charges.

### Plant Shortage and System Operation

Although a record amount of new plant was installed during 1950–51, the plant shortage was generally greater than in the previous year. In the winter of 1950–51 the shortage at the time of maximum potential demand,* which occurred on December 18, 1950, was 2219MW (sent out). This was equivalent to a sixth of the maximum potential demand, and it was estimated that the shortage would have been 2900MW if the weather had been extremely cold and there had been no load-spreading arrangements by industrial and commercial consumers. Load shedding was also more severe than in 1949-50.

The operation of the grid system was correspondingly more difficult. Not only has the grid to carry greatly increased loads, but because of the extent and incidence of the plant shortage it has also to provide for the transmission of large blocks of power from one part of the country to another, a function for which it was not designed. It was the rule rather than the exception for the loading of transmission lines to be critically high for some period of each day, and although no major disruption of supplies occurred, a serious fault might have led to extensive failure. In the continued attempt to minimise load shedding by operating the system up to and over its maximum safe capacity, risks of widespread failure of supplies had unavoidably to be taken.

### Electricity Progress and Requirements

As to the future, it was estimated early in 1950 that new generating plant would be brought into operation at increasing rates, as follows :—

| Calendar year | MW sent out |
|---|---|
| 1951 ... ... ... ... ... ... ... | 1000–1250 |
| 1952 ... ... ... ... ... ... ... | 1150–1400 |
| 1953 ... ... ... ... ... ... ... | 1300–1500 |
| 1954 ... ... ... ... ... ... ... | 1400–1600 |
| 1955 ... ... ... ... ... ... ... | 1500–1700 |
| 1956 onwards ... ... ... ... ... | 1600–1800 |

For each year the lower amount was that which could be expected with confidence, and the higher amount was that which should be possible if nothing affected existing plans.

It was explained in the second report (1949–50) that the Authority's plant programmes were planned after close consultation with the manufacturers of turbo-alternator and boiler plant, and that the sizes of the programmes were determined by the amount of manufacturing and construction capacity likely to be available. Their realisation, it was pointed out, would require a supreme effort on the part of all concerned; but they were physically capable of achievement, provided they were not affected by other national considerations (such as re-armament or restrictions on capital investment). Current uncertainties made it impossible to give any firm promise as to when plant capacity would be sufficient to meet all demands. But if the programmes were carried out (i.e., to give the higher amounts in the previous paragraph) and the growth in demand accorded with expectations, the shedding of load by switching off consumers should be comparatively infrequent by the winter of 1954–55 and very exceptional in the three following winters, even if the weather was extremely cold. Reductions in frequency and voltage, to a diminishing extent, would still occur during those four winters. Unless, however, the annual programmes of new generating plant could be speedily increased as planned, from the 1951 level of about 1,000MW (sent out) to at least 1,800MW in 1956, 1957 and 1958, it would be many years, on current expectations of the growth in demand, before full supplies could be given at all times.

This forecast was made before the launching of the re-armament programme and the deterioration in supplies of raw materials, and by the end of the year 1950–51 the probable impact of these developments had become a matter of serious anxiety. Already there were indications that plant manufacture and building construction were being adversely affected. Moreover, the forecast did not allow for any exceptional increase in the industrial demand for electricity such as must result from re-armament.

The Authority is convinced that, in the changed circumstances, the planned rates of new plant capacity will be impossible of achievement unless a top priority is given to the manufacture of power station plant and equipment and to power station construction. Even if a top priority is given and this enables the planned rates to be achieved, it will take several years to effect a substantial reduction in load shedding. And even if the use of load-controlling devices to reduce peak loads (referred to in the report) were to accord to industry an appreciable relief from load shedding, it could not materially affect the urgent need for the planned rates of new plant capacity, unless drastic and indefinitely prolonged restrictions were imposed on those consumers whose supplies were subject to control.

The Authority, therefore, is also seriously concerned about the proposal by the Government, in apportioning national capital investment, that the annual amounts of new generating plant should not rise beyond 1500MW† (sent out), compared with the present aim of 1800MW. The onerous and difficult nature of the Government's responsibility for ensuring the best use, in the national interest, of scarce materials, production capacity and labour is fully recognised; even with full employment it is not possible to produce quickly all the things the nation needs, and some allocation of resources, such as that made under the capital investment programme in respect of capital works, has to be made. But the proposed limit on the amounts of new plant would not only prolong the conditions of severe plant shortage and severe load shedding, but would also hinder that greater mechanisation and extended use of power in industry which can make the most effective contribution to improved industrial efficiency. With full employment increases in production can only come from better supplies of materials and improved efficiency, and there is abundant evidence that the much greater industrial output per man-hour in the U.S.A. than in this country is due in large measure to the much larger amount of power—two to three times as much—available per employee in the U.S.A. Even in the present difficult economic conditions, and whatever the expedients that may have to be adopted to relieve industry from the worst effects of load shedding, it is in the best national interest to make sure that the generating plant programmes are carried out as planned.

* "Potential demand" is the demand supplied by the power stations, plus the estimated amount of load reduction due to low frequency and to load shedding by reduction of voltage and disconnection of supply.

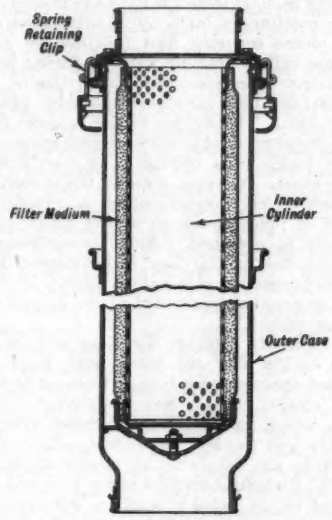
† A revised figure of 1550MW is given in the Electricity Report of the Minister of Fuel and Power for the year ended March 31, 1951.

## An Industrial Air Filter

An efficient filter medium, which was developed by a Government department and mainly used in respirators for the removal of smokes and toxic powders, has now been made available for industrial filtration, a licence to manufacture having been granted to Vokes, Ltd., of Guildford. The material is processed woollen fibres formed into lap in the presence of finely divided resin, which is subjected to friction during the process while the particles are excited and electrically charged. The charge not only helps to firmly bond the resin to the woollen fibres, but it is imparted to the airborne dust particles, causing them to be deposited or be attracted, resulting in an increased percentage removal of fine particles than by untreated fibres.

The problem of applying the new material to industrial purposes has been studied by the research department of Vokes, Ltd., and a method evolved, in conjunction with the Ministry of Works, resulting in the production of the canister unit which is illustrated in our drawing. The filter material is used as a deep bed so that a considerable dust load can be carried without causing a measurable rise in pressure loss; the filtration efficiency required can be met by varying the density and thickness of the material and also the pressure applied during assembly of the filter.

The specification of the first unit called for a filter capable of removing from the air bacteria and toxic bodies down to 0·2 micron, when taking air at 75 cubic feet per minute. As designed, the filter consists of a perforated cylinder with one end closed and the other connected to a metal duct, to the surface of which a special machine applies the filter material at the correct pressure, woven cotton gauze being used to maintain the amount of compression. An outer case completes the assembly and the final dimensions are 5ft 1½in overall length by 8½in diameter, which it is intended to standardise. Multiple unit filters can be assembled by using header ducts, which by incorporating sleeved connecting spigots,




AIR FILTER CANISTER

allow for easy removal of individual units. At the rated efficiency the air resistance amounts to 0·35in water gauge.

The performance of the filter is assessed by drawing the required volume of air through it with a cloud of methylene blue particles of known size and distribution (obtained by evaporating a 1 per cent solution of methylene blue dye in water), being in suspension in the air stream at the filter inlet. Air samples of filtered and unfiltered air are passed through a test paper to leave a methylene blue deposit and comparison of the air volumes required to cause similar stains on the test paper determines the efficiency.

At high efficiency the material is suitable for use in the protection of serums against cross infection of airborne bacteria, for the purification of air exhausted from toxic processes and the cleansing of air to operating theatres. Operating at reduced efficiency, it is effective in removing dust from air used in ventilating food-preparation factories and also in those producing films. When used at densities comparable with ordinary air-conditioning filters, the effectiveness of the new material, weight for weight, is more than double that of the normal fabric.

Lower density filters are being developed using the Vokes standard corrugated formation and a filter having 1in deep panels has been tested against one using untreated wool as a filter medium. The following table gives the relative performances.

| Air Velocity at Panel Face, f.p.m. | Untreated Wool | | Treated Wool | |
|---|---|---|---|---|
| | Air Flow Resistance inches w.g. | Efficiency per cent | Air Flow Resistance inches w.g. | Efficiency per cent |
| 40 | 0·11 | 25 | 0·13 | 94·4 |
| 80 | 0·23 | 25 | 0·24 | 95·2 |
| 120 | 0·35 | 25 | 0·37 | 95·7 |
| 160 | 0·43 | 20 | 0·50 | 95·2 |

## A Scrap Sheet Metal Baling Press

We illustrate below a new scrap metal baling press, introduced by Fielding and Platt, Ltd., of Atlas Works, Gloucester, which has been specially designed for baling of light sheet metal, in the form of clippings, shearings, off-cuts, waste oil drums, cans, &c.

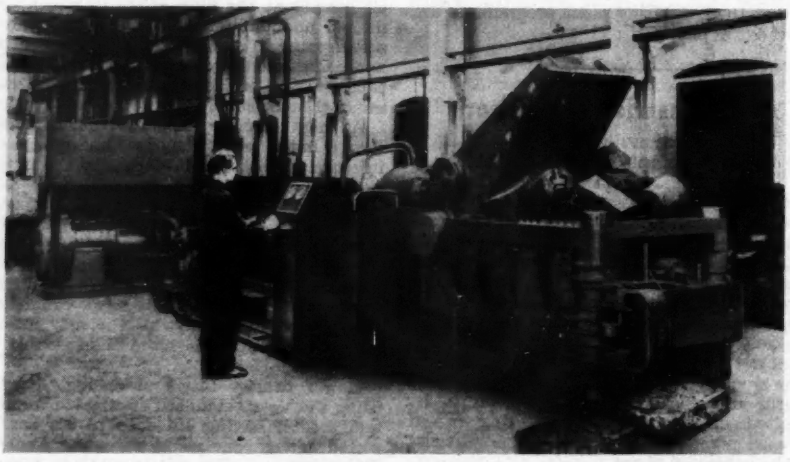
This 220 tons capacity machine is of the firm's single compression type and is fully self-contained with its own pumping unit, control panel and the necessary pipework. Operation of the machine is through two hand-wheel operated lapped-piston control valves, the valves being balanced to give ease of operation. Its production rate is dependent upon site and loading conditions but the approximate output is stated to be from eighteen to twenty bales, or up to 4 tons per hour, the weight of the bales ranging from 336 lb to 448 lb each.

The machine is built up of fabricated mild steel plates securely tied together so as to give the fullest possible rigidity during baling operations. The size of the box is 72in by 36in by 32in, the bale sizes being 36in by 18in by 8in to 12in. The insides of the box are fitted with special renewable steel wearing plates.

The machine is operated by two double-acting rams. One ram operates the hinged box shearing cover, through which a considerable degree of precompression of the loaded scrap material is obtained. Final compression of the material in the box is completed by a second horizontal ram, which is fitted with a pressing crosshead provided with a special steel wearing plate.

To facilitate loading, the sides and the top edges of the box are fitted with hard steel serrated shearing members, which, as the box cover closes, cut off any projecting ends of scrap, which would otherwise bend over and possibly jam the lid. Material too large to be placed in the box can be placed across the serrated shearing members of the box and then sheared off to suitable sizes by operating the cover downwards. The serrated shearing members are renewable and are provided with cutting edges formed along both sides, so that they can be reversed when one edge becomes blunt.

When loading the machine the box cover may be repeatedly used to cut off and tamp down initial loadings of scrap until the required weight of material has been loaded, whereupon the box cover is fully closed and final compression is carried out by the horizontal pressing crosshead. A massive door forming the end of the baling box can be swung open when the bale is finally compressed and the bale ejected by operating the horizontal ram.

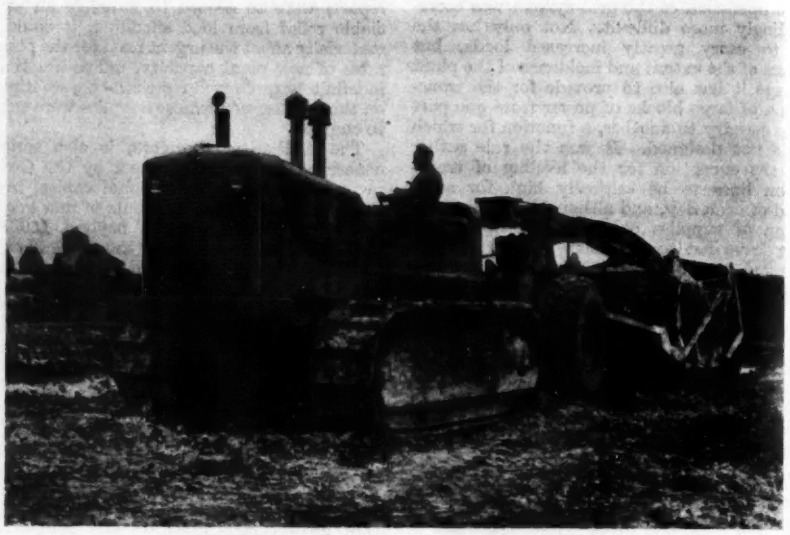


HYDRAULIC BALING PRESS

Hydraulic power for the operation of the press is provided by a two-stage radial pumping unit, driven by a totally enclosed fan-cooled electric motor. The pumping system uses oil as the pressure medium and pressures of 1500 lb to 2240 lb per square inch are used for the operation of the press. The whole unit, which weighs approximately 27 tons complete, has been specially designed for ease of installation with minimum operating and maintenance costs.

## Three Industrial Tractors

We are informed by Mackay Industrial Equipment, Ltd., Faggs Road, Feltham, Middlesex, that the first models of a new range of tractors made by the Allis-Chalmers Manufacturing Company of the United States, are now in operation in this country. Of the three new tractor models, the largest is the "HD20," and one of these machines can be seen in operation in the photograph reproduced above.



"HD20" TRACTOR AT WORK

This machine is driven by a General Motors six-cylinder, two-stroke diesel engine developing 175 b.h.p. normal rating and, in low gear, has a drawbar pull of 37,000 lb. Drive is taken through a three-stage torque converter designed to ensure that the maximum power available is employed at the maximum possible speed. The two forward gears provide a speed range from 0 to 3 m.p.h. in low and 0 to 7 m.p.h. in high gear. Track shoes 24in wide are fitted and provide a total ground contact of just over 5000 square inches for the machine, which weighs about 41,000 lb.

The machine has hydraulically controlled steering and is fitted with self-energising brakes to reduce fatigue on the part of the operator. To facilitate maintenance and repair all parts are designed for easy accessibility, and all major assemblies are arranged for easy removal without disturbing adjacent units.

Of the two smaller machines one, the "HD 15," is driven by a six-cylinder, two-stroke diesel engine, and develops 102 h.p. at the drawbar. Drive is transmitted through a constant-mesh transmission system giving six forward speeds from 1·39 to 5·80 m.p.h., and three reverse speeds from 1·54 to 4·51 m.p.h. As on the smaller "HD 9" machine, an automatic shift lock is incorporated in the gearbox to prevent accidental gear shifting whilst the master clutch is engaged. Hydraulically operated multi-plate steering clutches are fitted, together with self-energising brakes.

This machine weighs about 27,500 lb and when fitted with standard 20in wide shoes the ground pressure is 7·14 lb per square inch.

The smallest machine, the "HD 9," has a four-cylinder, two-stroke diesel engine and develops 70 h.p. at the drawbar. Its six forward speeds range from 1·39 to 5·68 m.p.h., and its three reverse speeds from 1·56 to 4·43 m.p.h., the machine's drawbar pull in first gear being 16,650 lb and in sixth gear 3525 lb at maximum engine revolutions.

In each of these two machines double reduction final drives provide good ground clearance, and the final drive and intermediate gears can be removed without disturbing the steering clutch.

The truck frames are fully oscillating, alignment being maintained by an "A" frame. Removal can be effected without disturbing the final drive sprocket or equiliser spring. Each truck frame has two top rollers, six bottom rollers and a front idler, the tapered roller bearings being protected by spring-loaded positive seals.

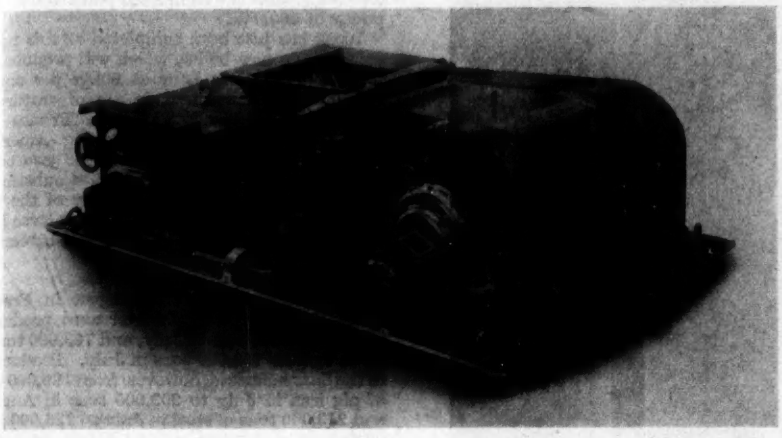
All of the machines are equipped with electric lighting and starter motor, radiator and sump guards, front pull hook, front bumper and truck wheel guards.

## A Mechanical Unit for Building Gateside Packs

We illustrate overleaf a mechanical builder for gateside packs which has been placed on the market by British Jeffrey-Diamond, Ltd., of Wakefield, and is claimed to be the first of its kind to be introduced to the mining industry. This machine, named the "B.J-D Junior Packmaster," is the result of several years of research in mechanical packing and stowing in mines.

It was developed as the makers considered that some form of mechanisation should be

applied to the work of packing, particularly the building of gateside packs. The need for such a machine, it is stated, became more apparent recently in view of the trend towards coal getting on one face on two or three shifts, and in connection with various continuous mining projects which are either in being or contemplated. It is also pointed out that in the building of gateside packs, particularly with thin seams, the work of casting dirt is monotonous and most expensive in manpower, as a number of men must necessarily be engaged in what is little more than a human shovel chain.



MECHANICAL BUILDER FOR GATESIDE PACKS

It is recognised that the best form of pack is one which is homogeneous, as such a pack offers more even resistance to roof pressures, and for this reason the new machine is designed to crush the ripping dirt before flinging it into the packhole. The crushed material is discharged into the packhole at a speed of approximately 60 m.p.h., which ensures the formation of a very tight pack. It is estimated that the reduction in volume obtained to contain a given quantity of ripping dirt is 25 per cent, compared with hand packing methods, and the makers say that it should be possible to fill all the ripping dirt into a packhole of reasonable dimensions to obviate necessity to send excess ripping dirt out of the pit.

To crush the very large pieces of rock with this small, compact unit, driven by a proportionately small motor, the material is fed into the rotor chamber of a special swing hammer crusher unit in which the hammer breaks off pieces of material, which are ejected from the machine at hammer speed. The machine, which is illustrated on this page, measures only 5ft 6in by 3ft 6in by 1ft 9in in height, and weighs approximately 1 ton. It consists of five main components—frame, rotor, bearings, drive, and power unit.

The frame is fabricated from heavy section steel and comprises a lower frame and removable upper case. The lower frame is built on a sledge plate and incorporates slide rails for the power unit, supports for the rotor bearings, and the lower part of the feed chute which is extended to form a breaking area. The upper case forms a guard for the rotor and incorporates the feed opening and the upper part of the feed chute. A baffle plate is incorporated to protect the operator.

The rotor consists of a single specially shaped hammer mounted on a hammer pin carried by two heavy end discs fitted to a large diameter shaft. This hammer is free to swing between the discs and its backward swing is arrested by a stop pin across the rear side. Double-row, self-aligning bearings on which the rotor is mounted take the thrust and radial loads, and the housings, which are separate units bolted to the lower frame, include efficient dust-excluding labyrinths.

The rotor is driven through vee ropes from either a continuously rated 15 h.p. flameproof squirrel-cage induction motor, or, alternatively, a 15 h.p. compressed air turbine. A waterspray attachment is built into the upper case for the effective suppression of dust.

The operation of the machine is given by the makers as follows.

At the beginning of the packing shift the machine is located in the roadway in the space from which the ripping was cleared on the previous shift; the metal sheeting on the face side of the new packhole and the waste wall is then erected, the "Junior Packmaster" is then pulled sideways under the ripping lip to be dropped, and in line with the new packhole; it is then sylvestered down the face and into the packhole so that the end of the machine is inbye of the breaking-off timber of the packhole before the ripping is dropped and filled into the machine; packing continues until a favourable moment arrives for the machine to be moved out into the gate itself; when the pack is complete, the machine is lying in the gate road under the section of roof which has just been ripped.

# American Engineering News

*(From our American Correspondent)*

## Prestressed Concrete Conference at M.I.T.

A series of interesting papers, presented under the headings of "Applications," "Materials," and "Design and Research," at the first American conference on Prestressed Concrete, constituted perhaps the most comprehensive review to date of the prestressed concrete structures planned or built in the United States. The conference was held at the Massachusetts Institute of Technology, at Cambridge, Massachusetts, from August 14th to 16th, and was sponsored by M.I.T., the American Concrete Institute, the American Institute of Architects, the American Railway Engineering Association, the American Society of Civil Engineers, the Associated General Contractors of America and the Portland Cement Association. The co-ordination of the conference was in the hands of Professor M. J. Holley, Jr., of the Department of Civil Engineering, Professor H. Simpson, of the Department of Building Engineering and Construction, and Professor E. N. Gelotte, of the Department of Architecture, of M.I.T.

In a series of papers describing the more important prestressed concrete projects in America, S. S. Baxter and M. Barofsky, of the Bureau of Engineering Surveys and Zoning, Department of Public Works, Philadelphia, reviewed the Walnut Lane Bridge at Philadelphia (THE ENGINEER, December 22, 1950), while K. H. Middendorf, of the Prestressed Concrete Corporation, Kansas City, and F. W. Panhorst, of the State Division of Highways, Sacramento, California, dealt with the pedestrian bridge over the Arroyo Seco flood channel in Los Angeles (THE ENGINEER, August 3, 1951). R. H. Bryan, of Bryan and Dozier, Nashville, Tennessee, gave an account of the Madison County Bridge in Tennessee. This bridge has a centre span of 30ft and two end spans of 20ft, each simply supported. It has a 19ft roadway. The beams were assembled on a slab in the shop, using 8in by 16in by 12in precast blocks mortared together, side by side. The prestressing strand was made of seven $\frac{7}{16}$in galvanised wires. Two strands were used for the 30ft span; one for the 20ft spans. After prestressing, the beams were delivered to the bridge site. Each beam was fully self-supporting and was easily placed in position by a crane. Additional strands were strung through holes in the sides of the beams for transverse prestressing of the entire group. All beams had a slight lip on the bottom so that when they were placed side by side there was a 2in free space between them. A concrete slab was poured over the beams, filling the openings and forming, for all practical purposes, a monolithic structure. After the concrete had hardened, the transverse cables were prestressed.

The "Preload" system of prestressing circular structures was described by Curzon Dobell, of Preload Enterprises, Incorporated, New York. The generally required watertightness of such structures is virtually guaranteed by prestressing in two directions—vertically and circumferentially. The circumferential prestressing wire is applied by a winding machine, which travels around the outside of the core wall. Moving under its own power, the "merry-go-round" accurately spaces and stresses the wire. This subjects the core wall to a horizontal compression sufficient to overcome the tensile stresses induced by the outward pressure of the liquid. The wire is initially stressed to about 140,000 lb per square inch; after prestressing it is bonded to the wall and protected from corrosion by coating with pneumatically applied concrete. The "Preload" system is now being used to construct four 205ft diameter prestressed concrete tanks at Chester, Pennsylvania. The system is also being used to make prestressed concrete pipe for a 40 mile pressure pipeline in Regina, Canada. The 36in diameter pipe has a 2in shell, designed to withstand an internal pressure of 280 lb per square inch. The subject of current prestressed pipe manufacture in the United States was also dealt with by J. G. Hendrickson, of the American Concrete Pipe Association, Chicago. The establishment of design standards was called for in a paper entitled "Why Prestressed Concrete?" by L. H. Corning, of the Structural and Railways Bureau, Portland Cement Association, Chicago. A review of European prestressed concrete practice in the field of bridge construction was presented by C. C. Zollman, of the Prestressed Concrete Corporation, Kansas City, and European building construction, involving prestressed elements, was outlined by N. Thorsen, of the Freyssinet Company, New York. In a closing summary, Rear Admiral J. F. Jelley, of the Bureau of Yards and Docks, U.S. Navy, stressed the importance of adapting European technique in the field of prestressed concrete to American construction requirements. He felt that the papers presented at the conference had shown beyond doubt that there exists in the United States to-day sufficient knowledge and experience to encourage an immediate more widespread use of prestressed concrete construction.

## A Metal-Treating Process for Cold Working of Steel

A new metal-treating chemical process, which is claimed to extend greatly the lubrication limits in the cold working of steel, consists of compatible cleaning, pickling and the application of a new phosphate coating and of specially developed lubricants to steel. A heat-resistant lubricating surface is produced which is chemically interlocked with the steel, and, therefore, possesses exceptional adherence even under the most severe working conditions. A result of joint research conducted by the Pennsylvania Salt Manufacturing Company and the Heintz Manufacturing Company, of Philadelphia, this "Foscoat" process has been demonstrated successfully in cold

extrusion and now awaits the general availability of press equipment of appropriate size and design to take advantage of the raised lubrication limits. Impressive results have been obtained in such applications as tube drawing, wire drawing, deep drawing, deep stamping, cold heading and similar cold working operations. In these operations there generally exist two limitations—lubrication and the ductility of the metal. The former limitation is said to be virtually eliminated by the chemically bonded lubrication film imparted to steel surfaces by "Foscoat." Economies claimed as a result of this improvement in lubrication include the elimination of intermediate press operations, as well as annealing and chemical treating operations, the reduced consumption of chemicals because of compatibility, the increased production with existing equipment, the savings in metal or reduction in scrap losses, and the considerable extension of the life of costly dies.

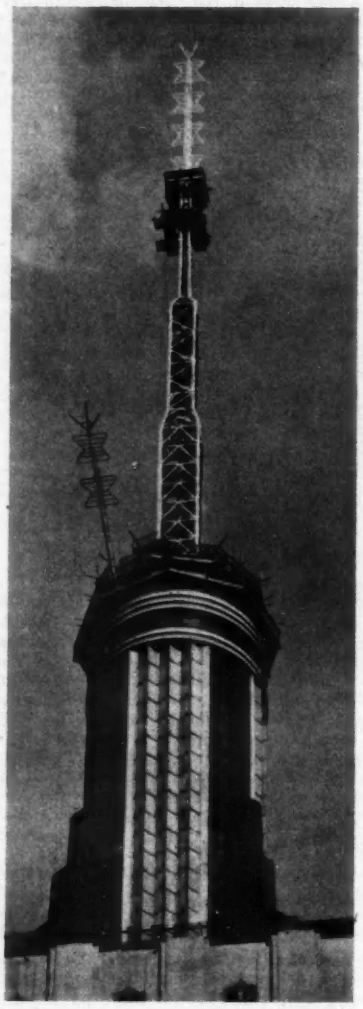
In the wet drawing of fine steel wire, for example, the commercial application of the "Foscoat" process resulted in a 40 per cent increase in the rate of production. Despite this increased rate of production, the die life was increased two and a half times. In dry drawing of steel wire shapes, such as triangle and square wire, from round stock, one application permitted drawing to finished shape without the intermediate annealing and recoating required in previous processes. The production use of the process has also made possible substantial savings in the fabrication of automatic washing machine tubs. Reductions in scrap losses due to rejects and in downtime for the stoning of dies have resulted in an increase of 140 per cent in output. In deep drawing of steel cartridge cases, 80 per cent reductions in wall thickness in the metal were found to be possible with a single application without intermediate annealing. This represents a 100 per cent improvement over conventional practice. In actual production in rod-pulled tube drawing, overall reductions of 80 per cent were achieved with a single application of "Foscoat," equivalent to a 60 per cent improvement over that previously obtained. In another tube mill, using plug drawing, overall reductions of 60 per cent were obtained with one application, which is also a 60 per cent increase over existing practice. In commercial cold extrusion, the process is said to be able frequently to eliminate the necessity for forging or upsetting of heated billets. Generally, a starting billet twice the size of that necessary for cold extrusion is required and the forged shape requires extensive scrap-generating machining.

"Foscoat" itself is a specially formulated phosphate coating, which can be applied by immersion, flooding or spraying, and forms a strong adherent coating, chemically bonded to the steel. This highly absorbent coating functions as a vehicle for an organic lubricant, which is designed to react chemically with the "Foscoat," in addition to being physically adsorbed and absorbed.

In view of the importance of proper precleaning and preparation for cold working, the complete process was worked out to include pickling and special alkaline cleaning. The process is now being used in regular operation in various cold-working plants in the United States. It has been employed successfully in conjunction with all grades of plain carbon steels and S.A.E. alloy steels as well as some medium alloy grades. It is not intended, in its present state of development, for use with the stainless and other high-alloy steels.

### Television Broadcasts From the Empire State Building

After eleven months of work on the 1250ft tall Empire State Building, in New York City, during which progress was often delayed by weather conditions, the new, permanent aerial of the National Broadcasting Company for its station WNBT is now in regular operation. The N.B.C. was the first organisation to transmit television programmes from the 215ft mast, which crowns the building tower and which is shown in the accompanying illustration. Four other television stations, which are to share the mast with WNBT, are expected to start transmissions from their respective aerials during coming months. The aerial is expected to give the WNBT station, which has a rating of 5kW, more effective coverage over a radius of 50 to 60 miles. The actual installation of the tower



EMPIRE STATE BUILDING TV AERIAL

and the aerials was accomplished under difficult working conditions and presented many unforeseen problems. Strong winds, storms, rain, cold and ice, delayed activity sometimes for weeks at a time. Frequently only one or two hours of work was possible in a full day. Ironically; there were numerous days when the weather on the ground was fair, the sun shining and the temperature mild, while high on the tower the wind blew at near-gale force.

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ASLIB AERONAUTICAL ENGINEERING GROUP.—Approximately 100 representatives of the aeronautical industry attended a meeting held at the Royal Aircraft Establishment, Farnborough, on September 27th, to inaugurate an Aeronautical Engineering Group of the Association of Special Libraries and Information Bureaux (ASLIB). This is one of a series of specialist groups that are being formed among ASLIB members to consider the recording and dissemination of literature and technical information in special fields. A committee was set up under the chairmanship of Mr. R. G. Thorne, Royal Aircraft Establishment, to control the work of the group and working parties were organised to consider the following subjects :—abstracting services, classification of aerodynamic data, Union Catalogue of the holdings of aeronautical libraries. The secretary of the group is M. C. W. Cleverdon, of the College of Aeronautics, Cranfield, Beds.

## French Engineering News

*(From our French Correspondent)*

The Marshall Plan administration has granted Electricité de France a credit of 1,100,000 dollars for the purchase of American plant for the "Arrighi" thermal-electric power station at Vitry sur Seine. This credit will enable a second 100MW set to be installed, work on the first having been started last year, when a credit of 4,000,000 francs was granted.

At the moment the "Arrighi" power station has four turbo-alternator sets of 50/55MW in service, so that the completed plant will have a power of 400MW.

Work has just been completed at this power station on a new boiler, which will produce 400 tons of steam per hour at 90kgs per square centimetre pressure and at a temperature of 520 deg. Cent. Electricité de France has stated that by carefully studying American material and the techniques of the two countries, it has been able to effect a substantial saving in dollars. While the body of the new installation is American, accessories have been made in France and all repairs will be carried out with French material.

* * *

Steel production fell in August in France. Some 704,000 tons of pig iron were produced, against 724,000 tons in July, and 763,000 tons of steel, against 796,000 tons in July. Production in the Saar increased, however, from 199,000 tons of pig iron in July to 203,000 tons in August, and 213,000 tons of steel in July to 226,000 tons in August.

* * *

The Sté des Aciéries de Longwy has published a report on modernisation. The work includes the construction and installation of several ovens and furnaces, including one at Mont-Saint-Martin. It will not come into service until 1953. At Thionville a convertor has been installed to enable the plant to use natural gas from Lorraine. The report states that production in 1950 was about the same as in 1949.

* * *

According to the accounts just published by Electricité de France, that body made a profit of 3 milliard francs in 1950, when production amounted to 37 milliard kWh. The increased consumption which is envisaged for the future, however, will necessitate spending 120 milliard francs on new constructional work. Thus, in spite of the present financial balance, tariffs are likely to be raised in the near future by 12 per cent. It is stated, however, that this will only be a temporary measure.

* * *

What is considered to be an unusually favourable site for a hydro-electric scheme is being investigated by engineers of Electricité de France in the Loire catchment. By constructing a diversion tunnel 17km long, in the Montpezat region, a head of 650m could be utilised, with relatively unimportant works to collect the hydraulic resources of the Loire basin, using the Issarles Lake.

The E.D.F. engineers' plan is, however, expected to cause much opposition. E.D.F. has had to agree to maintain sufficient flow in the Loire during dry periods and maintain the normal level of the Issarles Lake, at least during the tourist season. The average flow of the Loire near the Issarles Lake is 4 cubic metres a second, but varies considerably.

A small barrage will divert water into the lake. With the head of 644m, the 45 million cubic metres of water which will be diverted will produce 325 million kWh a year in the power station at Montpezat. Two 66MVA alternators, generating at 428 r.p.m. and 15kV, will each be driven by two Pelton turbines. The Issarles-Montpezat scheme will require the driving of 25km of tunnels. It is thought that the Montpezat power station will be ready for service in October, 1953, the entire scheme costing about 10 milliard francs.

* * *

An increase of about 22 per cent in the price of steel has been decided by the French Government, which also drew up an estimate of the sums needed to stabilise prices, amounting to 22 milliard francs up to December 31st.

# Industrial and Labour Notes

### Wage Claims

On Wednesday of last week a claim for a wage increase of £1 a week for engineering workers was presented to the Engineering and Allied Employers' National Federation. The claim was submitted by Mr. Jack Tanner, president of the Amalgamated Engineering Union, on behalf of the thirty-five unions affiliated to the Confederation of Shipbuilding and Engineering Unions. It may be recalled that the decision to put forward a demand for a wage increase was first taken at the annual meeting of the national committee of the Amalgamated Engineering Union last June. Subsequently, in August, the matter was discussed at the annual conference of the Confederation of Shipbuilding and Engineering Unions, the executive council of which was directed to proceed with the claim.

Representatives of the National Coal Board and the National Union of Mineworkers also held a meeting on Wednesday of last week to discuss the union's claim for a wage increase. The union is asking that the minimum weekly wage of underground workers should be increased by £1 3s. to £7 10s. and of surface workers by £1 to £6 10s. For piece-workers, the claim is for a flat rate increase of three shillings a shift. It has been estimated that, to meet the claim in full, £35,000,000 a year would be added to the National Coal Board's wages bill.

### Britain's Overseas Trade

Provisional figures issued last week-end by the Board of Trade show that the value of United Kingdom goods exported in September declined to £207,300,000, which was 8 per cent below the average for the preceding two months. Taking the third quarter of this year, however, the value of exports amounted to £655,400,000, which was 6 per cent above the average for the first six months. Over the first nine months of this year the annual rate of exports, according to the Board of Trade, was 16 per cent above the annual rate for 1950.

During September, the Board of Trade says, exports of United Kingdom goods, both to Canada and the U.S.A., declined. The value of exports to Canada was £8,500,000, or only 54 per cent of the peak value reached in July, while September exports to the U.S.A. were valued at £9,600,000, about £3,000,000 less than in August. During the third quarter of this year United Kingdom exports to Canada reached a total of £39,000,000, which was 13 per cent above the rate for the first half of the year, but exports to the U.S.A. in the third quarter, valued at £34,200,000, were 3 per cent below the rate for the first half of the year.

As to imports, the Board of Trade says that the upward trend of recent months was arrested in September, when the value of imports was £337,400,000, or £31,100,000 less than in August. In the first nine months of this year the value of imports was £2,921,000,000, compared with £1,908,000,000 in the corresponding period of 1950. With re-exports in September valued at £10,300,000, the excess of imports over exports during the first nine months of this year was £927,500,000.

### O.E.E.C. Technical Missions

Under the technical assistance scheme of the Organisation for European Economic Co-operation, three missions have recently left for study tours in the U.S.A. They will study, respectively, galvanising techniques, non-ferrous heavy metal fabrication, and smelting and refining of non-ferrous metals, visiting during their six-week tours several research centres and industrial undertakings. The United Kingdom is represented on the galvanising and metal fabrication missions.

Another O.E.E.C. mission, on which eight European countries are represented, will leave for Washington to-morrow. It is to study equipment for the oil industry and for that purpose will be divided into two groups, one specially interested in refining equipment and the other in drilling equipment. The British representatives on this mission have been selected from members of the Council of British Manufacturers of Petroleum Equipment. The Council's vice-chairman, Mr. Douglas Wilson, of The United Steel Companies, Ltd., will lead the British delegation.

### Iron and Steel Production

The British Iron and Steel Federation reports that production of steel ingots and castings in Great Britain during September averaged 302,900 tons a week. This represented an annual production rate of 15,749,000 tons, compared with a rate of 13,855,000 tons in August, and 16,964,000 tons in September, 1950. Over the first six months of this year steel production in this country was at an annual rate of 16,306,000 tons.

Pig iron production in September averaged 189,500 tons a week, which represented an annual rate of 9,854,000 tons. In September last year the annual production rate was 9,712,000 tons and over the first six months of the present year was 9,506,000 tons.

### The Accountant in Industry

The Institute of Cost and Works Accountants has submitted to its members a scheme to establish a Fellowship grade as a qualification in management accountancy. This scheme, it is claimed, will provide a qualification of high standing, which will benefit the accountancy profession as a whole and will also provide reliable evidence to industry of competence and experience in management accountancy.

When the scheme is approved the Institute will offer two grades of membership, namely, Associate Member for a qualified cost accountant and Fellow for a qualified management accountant. Both grades of membership, it is announced, are open to members of other recognised professional accountancy bodies. Fellowship of the Institute will be open to all Associate Members and to members of other accounting organisations, provided they pass the Fellowship examination in those subjects not adequately covered by their own examining bodies and comply with the Institute's conditions, which prescribe a minimum age limit of twenty-six, evidence of five years' experience in, and current engagement in, a responsible position in management accountancy.

### Productivity Teams for the U.S.A.

The Anglo-American Council on Productivity has announced the departure for the U.S.A. this week of two more productivity teams. The first has been selected from British manufacturers of metal-working machine tools and is complementary to the team concerned with wood-working machinery, which went to America in August. The metal-working machinery team is led by Mr. R. D. G. Ryder, managing director of Thos. Ryder and Son, Ltd., Bolton, Lancs. In addition to visits to representative plants in the U.S.A., producing metal-working machine tools, its programme includes conferences with manufacturers' associations and other bodies.

The other team—which is sponsored by the Institution of Works Managers, the Institution of Production Engineers, the Purchasing Officers' Association and the Federation of British Industries—is to investigate the administrative processes of production control from finality of design to dispatch. While touring widely diverse establishments in the eastern U.S.A., it is the team's intention to study, among other matters, the procurement of raw materials and components, the control and reclamation of scrap material, the planning and scheduling of output and material supplies and machine loading. The team also hopes to examine new developments in American practice, particularly those that are likely to have a bearing on the problem of limiting the amount of the "paper work" involved in production control. Mr. G. H. Way, chief planner of Dunlop Rubber Company, Ltd., is leading the team.

### The Effect of Welding on Health

The factory department of the Ministry of Labour has recently made an investigation into the possibility of ill-health arising from welding processes. The results have been set out in a booklet entitled "The Health of Welders," which has been published by H.M. Stationery Office (price 3s.).

The investigation included a survey of the various kinds of welding followed by the clinical examination of about 250 welders in different industries, supplemented in many cases by radiological examination of the chest and by blood tests. The main conclusions reached by the survey are that welders do not suffer from any specific disease that could be described as "welders' disease" and occupational dermatitis does not appear to be a frequent or serious cause of disability. The booklet says that electric welders may suffer from "arc eyes," without any permanent effect on the vision, and they also suffer to a greater extent than other workers from a slight, superficial inflammation of the eyelids. Among welders exposed to high concentrations of fumes, slight irritation of the throat is not uncommon, but the investigation revealed no serious effects on the throat or nose.

The booklet concludes with some general recommendations, pointing out that as the main risk of ill-health among welders is likely to be from fumes, the remedy is ventilation. It is recommended, for instance, that where oxy-acetylene welders are working there should be the same good general ventilation as for workrooms, where fairly hot processes are carried out and that where articles are electrically welded on benches or stands close localised exhaust ventilation should be applied. Other recommendations are that exhaust ventilation should be provided where the fumes contain substances in sufficient quantity to be poisonous or irritating, and that where welding is done in confined spaces exhaust draught should be provided as close to the welding point as possible.

### Employment and Unemployment

The Ministry of Labour has reported that, during August, the working population of Great Britain increased by 84,000 (47,000 men and 37,000 women) and at the end of the month totalled 23,449,000 (16,012,000 men and 7,437,000 women). The August increase, it is suggested, is attributable in large measure to the number of boys and girls leaving school and entering industry.

The total number of people in civil employment at the end of August was 22,402,000, or 70,000 more than at the end of July. Of that total, 4,194,000 were at work in the basic industries of the country. In those industries there were increases during August in the labour forces of agriculture, transport and gas, electricity and water undertakings, but there was a further drop in coal mining manpower, the number of wage earners on colliery books having fallen to 697,000 by the end of the month. In the manufacturing industries, 8,725,000 people were employed during August, or 42,000 more than at the end of July. The biggest increase in the staffs of these industries was in the "metals, engineering and vehicles" group, which added 25,000 to its labour force, bringing the number employed to 4,130,000 by the end of August.

The latest unemployment figures published by the Ministry of Labour relate to September 17th, when 217,028 people were registered as out of work, compared with 204,884 on August 13th. The September figure included 13,076 who were described as "temporarily stopped."

# Notes and Memoranda

## Rail and Road

RUBBERISED ASPHALT TRIALS AT AIRPORT.—The first airport perimeter track made from rubberised asphalt has been laid at Ringway Airport, Manchester. These experimental areas of bituminous asphalt incorporating natural rubber powder were laid down at the request of the Air Ministry on October 3rd and 4th. The test sections laid on the perimeter track comprise areas of 70ft by 30ft with control sections spaced between. Variations were made in the bitumen content of the mix to cover the normal tolerance of the specification and sections were also laid with different percentages of rubber which, in all cases, was added by predigesting the powder in the bituminous binder.

MIDLANDS AND SOUTH-WEST ROADS.—The British Road Federation has issued a booklet which stresses the need to improve road communications between the Midlands, South Wales and Bristol. In the Minister of Transport's ten-year plan for highway development, announced in 1946, the following proposals affecting the area were made :—A motorway of 76 miles from Birmingham to Almondsbury, just north of Bristol; a bridge over the Severn between Beachley and Aust; from Almondsbury a motorway which leads over this bridge and runs into South Wales, by-passing Newport; from Upton-upon-Severn, 17 miles north of Gloucester, a tributary motorway to just west of Ross; modernisation of the "heads of the valleys" road, the "South Wales ports" road, and the Cardiff–Merthyr road, by-passes at Port Talbot, Neath and Swansea, and completion of the Cardiff by-pass. The total cost of this part of the plan is estimated at £35,000,000. The booklet emphasises the steadily increasing interdependence of the economies of South Wales and the Midlands, and the enormous handicap imposed on a proper development of this economic liaison by the present inadequate roads. It points out that the proposed improvements for roads from the Midlands to the Bristol Channel ports and the industries of South Wales would, by reducing transport costs, reduce the cost of goods both for home and overseas markets. Further, they would ensure a balanced development of two complementary economies, and go far to establishing lasting prosperity in the areas affected.

## Air and Water

PERUVIAN NAVAL GUNBOATS.—The two shallow-draught river gunboats "Ucayali" and "Maranon," which were built by John I. Thornycroft and Co., Ltd., for the Peruvian Navy, have arrived safely at Iquitos on the upper Amazon. These vessels, each 155ft in length and driven by British Polar diesel engines, completed the voyage of 4000 miles from Southampton to Para and a further 2000 miles up the River Amazon, under their own power, in forty-four days. The 600-ton floating dock, also built by the same company, is being towed out and has arrived at Para.

CARGO HANDLING.—Those interested in the formation of an International Cargo Handling Co-ordination Committee have held a number of preliminary meetings which have resulted in the preparation of Provisional Articles of Association, and these are to be put forward for discussion at an international meeting to be held on board H.M.S. "Wellington," Embankment, London, on October 30, 1951. The object of the Committee is solely to study the methods by which the turn-round of ships in port can be reduced to a period of time consistent with the time spent at sea and the ship's speed. Upon the satisfactory completion of the work the organisation will be dissolved. Further particulars of the International Cargo Handling Co-ordination Committee and copies of the Articles of Association may be obtained from 110, Fenchurch Street, London, E.C.3.

## Miscellanea

OXFORD FARMING CONFERENCE.—The sixth Oxford Farming Conference will be held from January 8 to 10, 1952, the general theme being "Mechanisation, Labour and Profit." Particulars of the conference can be obtained from Mr. S. J. Wright, M.I.Mech.E., The Croft, Great Warley, Brentwood, Essex.

THE LATE MR. STANLEY CROFT.—We record with regret the death of Mr. Stanley Croft, which occurred at Torquay on October 6th. Mr. Croft, who was sixty-one, was the chairman and managing director of Stancroft, Ltd., Lancaster Street, Birmingham, a business which he founded originally in 1914 as the Shafting and Transmission Supply Company.

THE IRON AND STEEL SCRAP DRIVE.—To assist the recovery of iron and steel scrap from the farms in this country, Harry Ferguson, Ltd., has equipped and staffed a mobile office which recently started a tour of Kent. The office is preceded by one of the British Iron and Steel Federation's daylight cinema vans and an appeal is being made to all farmers to come forward with details of all obsolete metal equipment, no matter how rusty it may be. Having obtained particulars as to approximate quantities and localities of scrap, the office passes on the information immediately to the Federation's London and Southern Counties Joint Scrap Committee, which is arranging for merchants to collect the scrap and to make an "on the spot" offer for it to farmers.

NEW OFFICES AT THE WORKS OF BOULTON AND PAUL, LTD.—During the late war the works of Boulton and Paul, Ltd., at Norwich, were extensively damaged as a result of air raids, and in 1946 a comprehensive programme of reconstruction was prepared. Up to date the netting, fencing and woodworking sections have largely been rebuilt, and the final stages of the rebuilding of the constructional engineering departments are well in hand. Recently an important stage in the main programme was completed with the opening of a large new block of offices on the works premises. The new office block has a floor area of some 24,000 square feet and is situated at one corner of the 12-acre works site. In the five-storey building, it has once again been possible to bring together the administrative sections of the constructional woodworking, netting and fencing production departments, and the accounts, wages and other offices.

BRITISH ROPES, LTD.—Our attention has been drawn by British Ropes, Ltd., to an error which may lead to some confusion in the description of its "Paraflex" equal lay steel wire rope which appeared in our issue of September 7th last in the article on the exhibits at the Engineering and Marine Exhibition at Olympia. We said that this rope has six strands each of thirty-seven wires and went on to describe its construction. Actually, the rope has six strands each of thirty-six wires, and the layers of wires are made up as follows :—The outer layer has fourteen wires, the next layer is composed of seven large and seven small wires, the inner layer has seven wires, and there is a centre king wire. Constructed in this way all the layers have the same length of lay and all wires rest either on the crowns of wires or in the gussets between wires. There is no cross cutting and no secondary bending, as with the normal $6 \times 37$, where the wires in the different layers cross over each other.

SHEET AND STRIP METAL USERS' ASSOCIATION.—The winter conference of the Sheet and Strip Metal Users' Technical Association is to be held on Wednesday, Thursday and Friday, October 31st, November 1st and 2nd, at Charing Cross Hotel, London, W.C.2. The first day will be devoted to works visits. The annual meeting of the Association will take place at 10.30 a.m. on Thursday, November 1st, and in the afternoon of the same day a paper is to be presented by Mr. H. E. Dixon and Dr. H. G. Taylor on "Resistance Welding: Research Progress by the British Welding Research Association." The programme for Friday, November 2nd, includes discussions on "Tooling for Small Quantity Production" and "Materials Handling for Presswork and Assembly Lines." A sheet metal working exhibition, which is being arranged in the Charing Cross Hotel in connection with the conference, will be officially opened on November 1st. The secretary of the Association is Mr. Alastair McLeod, 49, Wellington Street, London, W.C.2.

NATIONAL FEDERATION OF ENGINEERS' TOOL MANUFACTURERS.—The annual general meeting and luncheon of the National Federation of Engineers' Tool Manufacturers was held in London on Wednesday, October 10th. Some sixty members and guests who attended the luncheon were addressed by the president of the Association, the Hon. R. A. Balfour, in the absence of Sir Alan Anderson, C.B.E., who was unable to attend as the principal guest owing to sudden illness. Mr. Balfour spoke of the effect that international politics now had on home industries and said that wider interest should be taken in the affairs of our neighbours. It was by being fully aware of events abroad, and in this case particularly on the Continent, that a successful commercial future could be established. Europe, he said, had received much assistance and must now look to itself for means upon which to build its commercial and industrial salvation, and it was in Europe that this country must take a closer interest. A brief speech welcoming the guests was given by Mr. S. J. Harley, and responded to by Mr. F. W. Halliwell.

EXPORTS OF FINISHED STEEL.—In order to ensure the proper distribution of exports of finished steel during the rest of the year the Board of Trade is revoking the current bulk licences which are valid for various destinations, endorsing them so as to exclude most foreign countries from their scope. The countries to which bulk licensing will continue will be the Commonwealth, Denmark, Finland, Norway, Portugal, Sweden and Argentina. Exporters desiring to export finished steel to other countries will be required to submit individual applications for licences. Holders of bulk licences will receive from the export licensing branch of the Board of Trade further information about the new arrangements.

THE GAUGE AND TOOL MAKERS' ASSOCIATION.—At a meeting of the Council of the Gauge and Tool Makers' Association following the annual general meeting on Tuesday, October 9th, it was decided to re-elect the officers of the Association for the new session 1951–1952. The officers of the Association for the session 1951–1952 will therefore be : Mr. F. W. Halliwell, M.I.Mech.E., M.I.Prod.E. (president), Mr. H. S. Holden, M.I.Prod.E. (chairman), Mr. A. L. Dennison, M.I.Prod.E., and Mr. L. E. Van Moppes (vice-chairmen), and Mr. R. Kirchner, M.I.Mech.E., M.I.Prod.E. (honorary treasurer). The Council decided to establish a new section of the Association for manufacturers of testing machines, and an application for membership of that section from W. and T. Avery, Ltd., has already been accepted. The other sections of the Association are for the manufacturers of gauges and measuring equipment; jigs, fixtures and special tools; press tools; moulds and dies, and diamond tools.

## Personal and Business

MR. W. N. DUFFY has been appointed publicity manager of Ferranti, Ltd., Hollinwood, Lancs.

MR. A. R. WRIGHT has been appointed a director of Lansing Bagnall, Ltd., Kingsclere Road, Basingstoke, Hants.

COLONEL G. G. H. BOLTON has been appointed chairman of the North-Western Division of the National Coal Board.

MR. J. A. ORIEL, F.R.I.C., and Mr. G. Ormsby Pearce have joined the board of W. J. Fraser and Co., Ltd., Dagenham, Essex.

H.R.H. THE DUKE OF EDINBURGH, K.G., F.R.S., has accepted honorary membership of the British Institution of Radio Engineers.

MR. RALPH CREDLAND has been appointed joint managing director of the Widnes Foundry and Engineering Company, Ltd., Widnes, Lancs.

JOHNSON AND PHILLIPS, Ltd., states that its Ipswich branch has been transferred to larger premises at 17, St. Nicholas Street, Ipswich (telephone, Ipswich 3417).

MR. IVOR W. SHELLY, M.I.Mar.E., has joined the staff of the marine sales department of J. Stone and Co. (Charlton), Ltd., Oceanic House, 1a, Cockspur Street, London, S.W.1.

BARR, THOMSON AND CO., Ltd., Kilmarnock, announces the appointment of Mr. William Manson as managing director. Mr. Manson joined the company as general manager in April, 1948.

MR. DONALD KING has been appointed chairman and Colonel J. H. Anderson has been appointed a director of the Globe Pneumatic Engineering Company, Ltd., 58, Victoria Street, London, S.W.1.

MR. E. J. WILSON, until lately assistant engineer to the Port of London Authority, has been appointed London office manager of Richard Sutcliffe, Ltd., 235, Vauxhall Bridge Road, S.W.1 (telephone, Victoria 0844).

GILFLEX CONDUITS, Ltd., is the new name of Flexible Non-Metallic Conduits, Ltd., Tottenham Court Road, London, W.1. The works, stores and main offices of the company are being transferred to 41, The Parade, High Street, Watford.

THE BRITISH ELECTRICITY AUTHORITY announces the following appointments :—Mr. A. Houghton Brown, M.I.C.E., senior civil engineer in the civil and building branch of the chief engineer's department; Mr. E. S. Booth, A.M.I.Mech.E., A.M.I.E.E., generation construction engineer; Mr. J. M. Drummond, deputy chief accountant.

THE BRITISH ALUMINIUM COMPANY, Ltd., states that Mr. S. M. Lawrence has been appointed assistant sales manager, unwrought and special products, in place of Mr. R. M. Warrington, who is relinquishing his appointment. Mr. O. M. Bruce Payne has taken over responsibility for the technical service section of the development department.

# British Patent Specifications

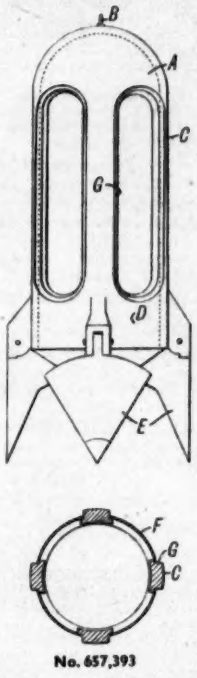
*When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.*

*Copies of specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.*

## CIVIL ENGINEERING

**657,393.** February 22, 1949.—Grab Bucket for Sinking Wells, Societe Française de Construction de Bennes Automatiques, of 57, Avenue Kléber, Paris, France.

The invention has for its object an improved grab bucket of the boring type for sinking wells. It comprises a substantially cylindrical elongated body of the lower end of which the bucket elements are pivotally connected. As shown in the drawing, the grab bucket comprises a one-piece body including a spherical cap *A* suspended to the cable *B*, a series of longitudinal uprights *C* leaving wide openings



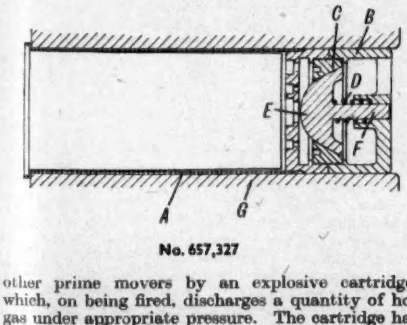

No. 657,393

between them, and a lower ring *D* provided with jaws. In the jaws the usual bucket elements *E* are pivoted on horizontal pins. The openings may be left completely free in the case in which the work is effected in water that does not contain gravel, or they may be provided with perforated metal sheets or with sieves *F* allowing the water to pass freely, but preventing the ingress of gravel larger than a given size into the mechanism or the bucket. The sieves are fixed in recesses *G* provided in the uprights.—*September* 19, 1951.

## INTERNAL COMBUSTION ENGINES AND GAS TURBINES

**657,327.** October 4, 1948.—Starting Means for Prime Movers, Rotax, Ltd., of Rotax Works, Victoria Road, Willesden Junction, London, N.W.10 (*Inventor: John Charles Frederick Whicker*).

This invention has for its object the provision of improved means for starting gas turbines or

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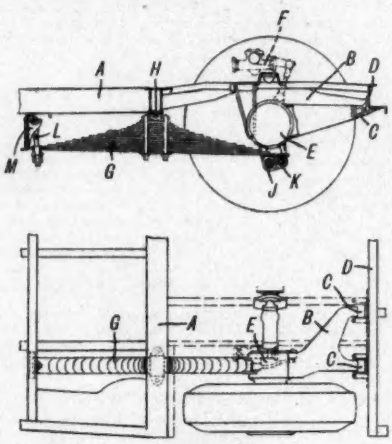
other prime movers by an explosive cartridge, which, on being fired, discharges a quantity of hot gas under appropriate pressure. The cartridge has a non-return valve combined with its outlet. Referring to the drawing, the cartridge comprises a cylindrical shell *A* for containing the explosive material. At the discharge end of the shell a non-return gas discharge valve is provided. The valve comprises a hollow nose piece *B* which is provided with an annular seating *C* and a member loaded by a spring *D*. The closure member comprises a head *E* and a stem *F* supported in the axial bore in the nose piece and surrounded by the spring. The cartridge is held in the bore of a block *G* at one side of the prime mover. On firing, the gases pass through the valve and into the prime mover for setting it in motion. By the combination of a spring-loaded non-return valve integrally with the cartridge, the discharged gases are prevented from returning into the shell, and a feature which is especially desirable is that provision is made on the prime mover for accommodating a number of cartridges which can be fired in succession, each cartridge being fitted with its own non-return valve.—*September* 19, 1951.

## ROAD TRANSPORT

**657,466.** February 24, 1949.—Spring Mounting of the Rear or Non-Steered Wheels of Vehicles, A/S Strommens Vaerksted, Strömmen, near Oslo, Norway.

In the drawings, the vehicle chassis frame *A* has pivot arm *B* mounted on a pivot *C* secured to a transverse beam *D* of the frame. The pivot arm carries the wheel bearing *E*. To the top of the wheel bearing is attached a shock absorber *F*. A leaf spring *G* rests, with freedom to swing, against the frame at *H*, and a free end of it extends below the wheel bearing *E* and rests on two rollers *J* and *K* carried by the wheel bearing. The other end of the spring is attached to the chassis through a link *L*. This link has a T-shaped head formed with knife edges by means of which it is suspended from two brackets *M* on the frame. The other end of the link carries a knife edge that rests against the

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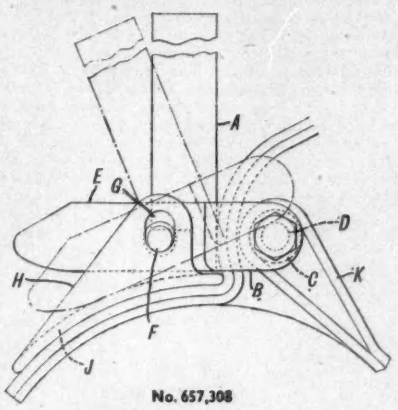
underside of the spring and is kept in position by nuts. The novel feature of this construction resides in the fact that a line along the underside of spring *G* and a line drawn from the axis of the pivot *C* through the point where the spring rests on rollers *J* and *K*, enclose an obtuse angle the apex of which is directed downwards. Due to this fact an increased load on the vehicle will cause the rollers, which interconnect the wheel shaft and the spring, to move in direction towards the middle of the spring, whereby the effective length of the spring is reduced, with the effect that its resistance is increased. Thus, the arrangement causes the spring pressure to be increased upon an increased load. As the end of the spring is attached to the chassis by means of the link through knife-edge abutments, shackles and their lubrication or greasing are avoided, and friction is reduced to a minimum.—*September* 19, 1951.

## WORKSHOP TOOLS AND APPLIANCES

**657,308.** April 17, 1948.—Gripping Devices for Pipes and Rods, E. Pass and Co., Ltd., of Station Works, Denton, Lancaster, and Frank Cooke, of the company's address.

The gripping device described comprises a lever *A* to the lower end of which are welded arms *B* forming a toe-like extension, between the outer ends of which is a fixed collar *C* carried by a rivet *D*. Also attached to the lower end of the lever is a projecting heel-like extension *E*. The lever is furnished with two outward projecting pins *F*. These pins are pivotally and slidably located one in each of slots *G* in the upstanding end portions *H* of an arcuate shoe or slipper *J*. The device is used with a strap *K* and the collar *D*, on the toe extension, is located in a bight of the doubled strap, the two ends of the strap, after being passed round the pipe, being passed under the shoe or slipper *J* and between the arms *B*. In operation, the device is initially disposed as shown in full lines in the drawing, the strap being pulled tight. As the lever is rotated to the position shown in chain lines, the heel extension *E* makes contact with the shoe *J*, and is fulcrumed on it. The pins *F* being free to

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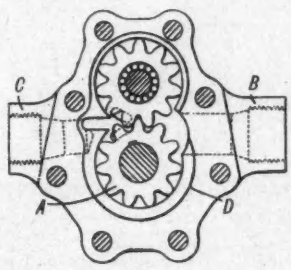
rise in the slots *G* do not interfere with the upward movement of the toe to effect the gripping action of the strap on the pipe. The radial or downward pressure on the pipe, as the heel rolls on the shoe, is spread over the area of the shoe in contact with the strap, and therefore the danger of collapse of the pipe, due to the pressure exerted by the end of the lever is eliminated.—*September* 19, 1951.

## PUMPS

**655,031.** April 4, 1945.—Leakage Prevention Devices for Hydraulic Pumps, Integral, Ltd., Consins Street, Dudley Road, Wolverhampton, Staffordshire (*Inventor: Ronald Frederick Worlidge*).

The operation of the pump is shown in the drawing. The lower gear *A* rotates clockwise, and hydraulic fluid is pumped from an inlet at *B* and delivered to a pressure outlet *C*. A pressure relief groove *D* in the end face of the casing is provided. When the pump is in operation the pressure of the fluid is a minimum in the vicinity of the inlet *B* and increases to a maximum at the outlet *C*. This pressure tends to produce a leakage of fluid between the abutting faces of the two parts of the casing, and in order to check this leakage it is necessary to give a high finish by lapping or diamond turning. According to the invention

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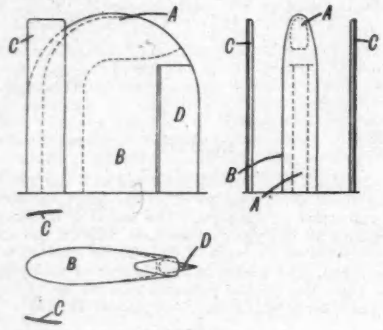
interface leak is eliminated by providing a small groove in one or both of the abutting faces of the pump, the groove communicating with a lower pressure point of the pump, and being of such dimensions as may be produced by a scriber or similar hand tool. Such a groove is shown at *D*. It surrounds the recess in the casing in which the gears rotate breaking into the recess near the inlet *B*. The dimensions of the groove may vary in accordance with the delivery pressure of the pump, but as an example a groove of 20 mils maximum width and 15 mils maximum depth has been found adquate for pressures up to 2000 lb per square inch. The groove so formed renders unnecessary very high finish on the abutting surfaces and, with an ordinary fine machine finish, the outside of the pump runs dry.—*July* 11, 1951.

## MISCELLANEOUS

**657,365.** February 9, 1949.—Chimneys or Funnels for Land Vehicles or Marine Craft, Societe des Forges et Chantiers de la Mediterranee, of 25, Boulevard Malesherbes, Paris, France, and Jacques Valensi, of 391, Rue Paradis, Marseilles, France.

This invention relates to chimneys or funnels for land vehicles or marine craft, and consists of an improvement in or modification of the invention described in Specification 639,875. In the drawings

a side elevation of a chimney having two front or fore slots and a slotted aileron at the rear is shown with a plan view and a front elevation. The smoke outlet is shown at *A*, the fairing or streamlining at *B*, the slot-forming devices to be used to build up the fore slots at *C*, and the rear slotted aileron at *D*. The fairing has the form of an aerofoil of symmetrical bi-convex cross section, of 20 per cent maximum thickness ratio at 30 per cent from the leading edge, the lengths being referred to the mean chord of the aerofoil. The rear aileron *D* is of height about three-quarters of that of the fairing *B* and of a depth equal to about one-quarter of its height, its axis of rotation being set in such a way that any trimming or lateral orientation of the aileron opens a slot in the aerofoil. When trimmed the slotted aileron *D*, together with the fore slots between the parts *C* and *D*, improves the coefficient of aerodynamic force of the fairing. The aileron can be trimmed or oriented at a variable angle in

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relation to the plane of symmetry of the fairing, to suit the incidence angle of the relative wind. There is thus obtained a variable-slot aerodynamic system which ensures that the marginal vortex formed at the rear of the free end of the fairing, by the action of the relative wind, is maintained when the incidence angle of said relative wind exceeds the limiting value (about 25 deg.) at which the marginal vortex normally ceases to be produced. Thus, the marginal vortex may remain undestroyed, even at very high incidences of the relative wind; the trimming of the aileron *D* also prevents the smoke from being beaten down, for an incidence angle of 90 deg., as would happen with a plain aerofoil. The aileron *D* may be operated by hand or automatically by a servomotor device controlled by a vane arranged to swing in response to the direction of the relative wind. To provide for the operation of the chimney when the vehicle or craft is stationary and there is no relative wind, or also when the relative wind blows from the rear to the front of the ship, there may be provided within the fairing an additional outlet for the smoke, which outlet is controlled by means of a valve or shutter making it possible to discharge the smoke upwards.—*September* 19, 1951.

# Forthcoming Engagements

*Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the* TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

### Association of Supervising Electrical Engineers

*Mon., Oct. 22nd.*—SHEFFIELD BRANCH: Royal Victoria Hotel, Sheffield, Lecture and Demonstration, "Television," P. Williamson and C. O. Birtles, 7.30 p.m.

*Thurs., Oct. 25th.*—KENT BRANCH: Sun Hotel, Chatham, Film Show, 8 p.m.

*Mon., Oct. 29th.*—BOURNEMOUTH BRANCH: Grand Hotel, Firvale Road, Bournemouth, Film Show, 8.15 p.m.

### Illuminating Engineering Society

*To-day, Oct. 19th.*—HUDDERSFIELD GROUP: Technical College, Queen Street South, Huddersfield. "Light, Colour and the Stage," E. E. Faraday, 7.15 p.m.

*Mon., Oct. 22nd.*—SHEFFIELD CENTRE: The University, Western Bank, Sheffield, "Radiation: Lighting and Illumination," J. N. Aldington, 6.30 p.m.

*Thurs., Oct. 25th.*—BRADFORD GROUP: Yorkshire Electricity Board, 45-53, Sunbridge Road, Bradford, "The Application of Modern Flash Discharge Tubes," C. R. Bicknell, 7.30 p.m.

*Mon., Oct. 29th.*—LEEDS CENTRE: Lighting Service Bureau, 24, Aire Street, Leeds, 1, "Festival Year in Britain," T. O. Freeth, 7 p.m.

### Institute of British Foundrymen

*Sat., Oct. 20th.*—BRISTOL AND W. OF ENGLAND BRANCH: Grand Hotel, Broad Street, Bristol, "Some Casting Defects," H. Balme, 3 p.m.

*Wed., Oct. 24th.*—N.E. SCOTTISH SECTION: University College, Dundee, Joint Meeting with the Dundee Institute of Engineers, speaker R. R. Taylor, 7.15 p.m.

*Fri., Oct. 26th.*—FALKIRK SECTION: Temperance Cafe, Lint Riggs, Falkirk, American Gating Film, 7 p.m.

### Institute of Industrial Administration

*Wed., Oct. 24th.*—LONDON CENTRE: Management House, 8, Hill Street, Berkeley Square, W.1, "Management in Practice": No. 2, "Attitudes," S. Waugh, 7 p.m.

### Institute of Industrial Supervisors

*Thurs, Oct. 25th.*—S. WALES AND MONMOUTHSHIRE SECTION: Simmonds Aerocessories, Treforest, Murex Sound Colour Film, "Hard Metal." 7 p.m.——NEWARK SECTION: County Technical College, Newark, Industrial Film Show, including Motion Study Films, 7.30 p.m.

*Fri., Oct. 26th.*—GLASGOW SECTION: Royal Technical College, Glasgow, "The Foreman and the Factories Acts," K. G. Tupling, 7.30 p.m.

### Institute of Metals

*Thurs., Oct. 25th.*—BIRMINGHAM LOCAL SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, Debate, "That in the opinion of this House further encroachment of Metal Physics into the sources of instruction would be detrimental to training in Metallurgy," opening speakers J. W. Jenkin and H. W. G. Hignett, 7 p.m.

### Institute of Navigation

*To-day, Oct. 19th.*—**Royal Geographical Society, 1, Kensington Gore, S.W.7, Presidential Address, "Navigation and the Shipping Industry," Sir Robert Watson-Watt, 3 p.m.**

### Institute of Welding

*Tues., Oct. 23rd.*—N. LONDON BRANCH: Slough Community Centre, Farnham Road, Slough, Bucks, Question Night, 7.30 p.m.

### Institution of Chemical Engineers

*Sat., Oct. 20th.*—N.W. BRANCH: College of Technology, Manchester, "Chemical Engineering and the Future," Sir Harold Hartley, 3 p.m.——MIDLANDS BRANCH: The University, Edmund Street, Birmingham, "Recovery of Sulphur Dioxide from Effluents Obtained in Sulphuric Acid Manufacture," L. Moller, 3 p.m.

### Institution of Civil Engineers

*Tues., Oct. 23rd.*—PUBLIC HEALTH ENGINEERING DIVISION: Great George Street, Westminster, S.W.1, "Relation between Daily Rainfall and Flow of the River Shin," R. H. MacDonald, 5.30 p.m.

### Institution of Electrical Engineers

*Mon., Oct. 22nd.*—Savoy Place, London, W.C.2, Discussion on "The Place of Electricity in a National Fuel Policy," 5.30 p.m.

*Tues., Oct. 23rd.*—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, Chairman's Address, F. J. Lane, 5.30 p.m.——SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "The Protection of Electrical Power Systems: A Critical Review of Present-Day Practice and Recent Progress," H. Leyburn and C. H. W. Lackey, 7 p.m.——E. MIDLAND CENTRE: Gas Demonstration Theatre, Nottingham, "The Planning of an Electricity Board's Distribution System," G. O. McLean, 6.30 p.m.

*Thurs., Oct. 25th.*—SCOTTISH CENTRE: Temperance Hotel, Lint Riggs, Falkirk, "Lightning," F. M. Bruce, 7.15 p.m.——UTILISATION SECTION: Savoy Place, London, W.C.2, Chairman's Address, A. H. Young, 5.30 p.m.

### Institution of Engineers and Shipbuilders in Scotland

*Tues., Oct. 23rd.*—39, Elmbank Crescent, Glasgow, "Marine Development in Aluminium," J. Venus, 6.30 p.m.

### Institution of Mechanical Engineers

*To-day, Oct. 19th.*—Storey's Gate, St. James's Park, S.W.1, Address by the President, A. C. Hartley, 5.30 p.m.

*Mon., Oct. 22nd.*—SCOTTISH BRANCH, GRADUATES' SECTION: Visit to Hiram Walker and Sons (Scotland) Ltd., High Street, Dumbarton, 7.15 p.m.

*Tues., Oct. 23rd.*—S. WALES BRANCH: Visit to National Oil Refineries at Llandarcy, followed by paper "Mechanical Engineering in an Oil Refinery," H. W. Murphy.——YORKSHIRE BRANCH, GRADUATES' SECTION: Visit to Yorkshire Copper Works, Leeds, 7 p.m.——BIRMINGHAM A.D. CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham "Independent Rear Suspension," Donald Bastow, 6.45 p.m.——LUTON A.D. GRADUATES' SECTION: Town Hall Assembly Room, Luton, "The B.R.M.," Raymond Mays, 7.15 p.m.

*Wed., Oct. 24th.*—SOUTHERN BRANCH: Transport Equipment (Thornycroft), Ltd., Basingstoke, "The B.R.M.," Raymond Mays, 7 p.m.——YORKSHIRE BRANCH: Mappin Hall, The University, Sheffield, "Technical Developments in Broadcasting," A. G. S. Smith, 7 p.m.

*Thurs., Oct. 25th.*—WESTERN A.D. CENTRE: Royal Hotel, Bristol, "Experiences During Twenty Years of Oil Engine Development," C. B. Dicksee, 6.45 p.m.

*Fri., Oct. 26th.*—Storey's Gate, St. James's Park, S.W.1, "The Principles of Continuous Gauge Control in Sheet and Strip Rolling," W. C. F. Hessenberg and R. B. Sims, 5.30 p.m.

### Institution of Mining Engineers

*Sat., Oct. 27th.*—Prince of Wales Hotel, Harrogate, "Strata Control and the Influence on Underground and Surface Damage," N. E. Webster, 11.15 a.m.

### Institution of Post Office Electrical Engineers

*Wed., Oct. 24th.*—Conference Room, Fourth Floor, Waterloo Bridge House, London, S.E.1, "Miscellaneous Services," J. Stratton, 5 p.m.

### Institution of Production Engineers

*Mon., Oct. 22nd.*—LUTON GRADUATE SECTION: Town Hall, Luton, "Production of the Comet Aircraft," H. Povey, 7.30 p.m.——MANCHESTER SECTION: College of Technology, Sackville Street, Manchester, "Some Tapping Experiments: Accurate Thread Production and Breakage Elimination," E. Johnson, 7.15 p.m.

*Tues., Oct. 23rd.*—COVENTRY SECTION: Geisha Cafe, Hertford Street, Coventry, "Factory Lay-Out," R. Gore, 7 p.m.

*Wed., Oct. 24th.*—DUNDEE SECTION: Visit to the National Cash Register Company (Manufacturing), Ltd., Kingsway West, Dundee, Angus, 7.30 p.m.——LONDON GRADUATE SECTION: 36, Portman Square, W.1, "How the Money Moves in Business," T. G. Rose, 7.15 p.m.

*Thurs., Oct. 25th.*—S. WALES SECTION: S. Wales Institute of Engineers, Park Place, Cardiff, "The Craftsmanship of Output as Applied to the Processing of American Brassfoundry Work," F. E. Rattlidge, 6.45 p.m.

### Institution of Structural Engineers

*Wed., Oct. 24th.*—11, Upper Belgrave Street, London, S.W.1, "Some New Developments in Prestressed Concrete," P. W. Abeles, 5.55 p.m.

*Fri., Oct. 26th.*—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, Chairman's Address, W. H. Veal, 6 p.m.

### Junior Institution of Engineers

*Sat., Oct. 20th.*—N.W. SECTION: Manchester Geographical Society, 16, St. Mary's Parsonage, Manchester, "Time Recording," W. J. Thompson, 2.30 p.m.

*Mon., Oct. 22nd.*—SHEFFIELD AND DISTRICT LOCAL SECTION: Co-operative Educational Centre, 201, Napier Street, Sheffield, 11, Annual General Meeting, "Engineering on the North-West Frontier," E. P. Hall, 7.30 p.m.

*Wed. to Fri., Oct. 24th to 26th.*—39, Victoria Street, Westminster, S.W.1, Exhibition, showing exhibits with historic connections with the Institution, 9.30 a.m. to 7.30 p.m., last day to 8.30 p.m.

### Liverpool Engineering Society

*Wed., Oct. 24th.*—24, Dale Street, Liverpool, "The Gerritsen Gear," J. J. Gerritsen, 6 p.m.

### Liverpool Joint Chemistry Committee

*Thurs., Oct. 25th.*—Chemistry Lecture Theatre, The University, Liverpool, "Some Recent Work on Large Ring Compounds," W. Baker, 4.30 p.m.

### Liverpool Metallurgical Society

*Wed., Oct. 24th.*—Visit to the works of the Automatic Telephone and Electric Company, Ltd.

### Manchester Association of Engineers

*To-day, Oct. 19th.*—Engineers' Club, Albert Square, Manchester, "Electrical Power Distribution in Factories," E. Jacks, 6.45 p.m.

### North-East Coast Institution of Engineers and Shipbuilders

*Fri., Oct. 26th.*—Stephenson Building, King's College, Newcastle upon Tyne, "Photography at Sea of Ship Propeller Cavitation," J. W. Fisher, 6.15 p.m.

### Society of Chemical Industry

*Tues., Oct. 23rd.*—Geological Society, Burlington House, Piccadilly, W.1, "Some Sulphur Recovery Processes in Refining Operations," G. M. Rowell, 5.30 p.m.

### Stephenson Locomotive Society

*To-day, Oct. 19th.*—32, Russell Road, Kensington, London, W.14, "Brighton Locomotive Reminiscences," L. Billington, 6.45 p.m.

*Sat., Oct. 20th.*—N.E. AREA: Y.M.C.A., Albion Place, Leeds, "Some Locomotives I Have Travelled Behind," C. Hutton, 2.30 p.m.——SCOTTISH CENTRES: British Railways Offices, 302, Buchanan Street, Glasgow, "South Country Happenings of 1951," O. S. Nock, 7.30 p.m.

# Contracts

VICKERS-ARMSTRONGS, Ltd., has received from Alfred Holt and Co. a repeat order for a 8300-ton cargo liner. The ship, which will have a length between perpendiculars of 452ft 9in by 62ft beam by 35ft 3in depth, will be driven by Harland-Burmeister and Wain diesel engine at a speed of 16 knots.

DURING the past month the British Electricity Authority has placed contracts for equipment for power stations, transforming stations and transmission lines amounting in the aggregate to £2,742,613. The principal contracts include:—Acton Lane "B" power station, Willesden, one 240,000 lb per hour boiler and coal transportation plant (Mitchell Engineering, Ltd.); Tilbury power station, coal unloading cranes (Stothert and Pitt, Ltd.); Drakelow power station, Burton-on-Trent, cooling tower (Mitchell Construction Company); Meaford "B" power station, near Stone, Staffs, high-pressure pipework and valves (Babcock and Wilcox, Ltd.), and auxiliary switchgear and accessories (A. Reyrolle and Co., Ltd.); Stourport "B" power station, high-pressure steam piping (Aiton and Co., Ltd.); Connah's Quay power station, Chester, generator transformers (C. A. Parsons and Co., Ltd.), and auxiliary switchgear (A. Reyrolle and Co., Ltd.); Chadderton power station, Oldham, 3·3kV auxiliary switchgear and accessories (English Electric Company, Ltd.); Roosecote power station, Barrow, condensing water system (Bierrum and Partners, Ltd.); Goldington power station, Bedford, 132kV, 2500MVA switchgear (A. Reyrolle and Co., Ltd.); Three Bridges substation, Sussex, 132kV, 2500MVA switchgear (English Electric Company, Ltd.); and Stella South, Blaydon-on-Tyne, 132kV, 3500MVA switchgear (A. Reyrolle and Co., Ltd.).